



# RAPTOR RESEARCH

A Quarterly Publication of The Raptor Research Foundation, Inc.

VOLUME 20, NUMBER 1, SPRING 1986

(ISSN 0099-9059)

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Provo, Utah

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Published quarterly by The Raptor Research Foundation, Inc. Business Office: Jim Fitzpatrick, Carpenter Nature Center, 12805 St. Croix Trail, Hastings, Minnesota 55033, U.S.A.

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VOL. 20

SPRING 1986

No. 1

## POPULATION ECOLOGY OF THE HARRIS' HAWK IN ARIZONA

WAYNE H. WHALEY

**ABSTRACT** - The Harris' Hawk (*Parabuteo unicinctus*) was studied in Arizona during 1976-1977. Where 2 separate populations once resided in Arizona, 1 now remains and occupies 3,880 km<sup>2</sup> of the Arizona Upland subdivision, Sonoran Desert. The former population along the Colorado River is extirpated.

Nests were built or old nests repaired from January to August and eggs were laid from mid-January to mid-August. Subsequent clutches were documented in 50 nesting ranges. Occasionally second clutches were laid before young of first broods were fledged. Fledging dates ranged from April to October. At 9 locations active nests were 0.8 km apart and at 2 locations nests were 0.5 km apart. Within 2 study areas nesting density was 2.5 km<sup>2</sup>/active nest. In 1977 Harris' Hawks reoccupied 91% of the nesting ranges used in 1976. More than 2 adults were observed at 46% of 227 nesting ranges.

Productivity for 396 nesting attempts averaged 3.16 eggs/clutch and 1.62 young fledged/nesting attempt. Seventy-four percent of the nesting attempts were successful.

Food consisted mainly of rabbits and ground squirrels. Mortality occurred mainly during the egg laying and incubation period. Early nest failures resulted in second broods, but successful pairs also had second broods. Habitat loss is the major cause of decline of the population followed by excessive human disturbance.

Research on raptors has become increasingly important as a result of the marked decline in several species over the past 3 decades (Arnold 1954; Cottam et al. 1961; Berger, Sindelar and Gamble 1969; Peterson 1969; Sprunt 1969; Henny and Wight 1972).

In the southwest, particularly in Arizona, the ranges of some species of raptors extend marginally into the United States, and here population studies are usually most informative. Most of these border species have received little investigation. For example, the Aplomado Falcon (*Falco femoralis*) showed signs of decline as early as 1890 (Phillips, Marshall and Monson 1964). Its range and status in Arizona was poorly documented (Phillips et al. 1964) until the study of Hector (1975). Where it was once thought to be locally fairly common, it is extinct (Hector 1975). Because of habitat destruction, Gray Hawk (*Buteo nitidus*) populations have declined during the last century (Richard Gliniski pers. comm.).

The Harris' Hawk (*Parabuteo unicinctus superior*) is another relatively unstudied southwestern raptor. Studies by Hensley (1959) and Mader (1975a, 1975b, 1977) are the only major works on this species in Arizona. Because of sudden decline and

apparent extinction in southern California (R. Guy McCaskie pers. comm.), and with the recent (late 1960) increased use for falconry, knowledge of the Harris' Hawk's status in Arizona is critical.

The primary purpose of this study was to establish base-line data on nesting distribution and abundance of the Harris' Hawk in Arizona and to compare these data with the historic record to determine nesting success of the present population.

### STUDY AREA AND METHODS

Arizona falls into a southwestern bi-seasonal climatic pattern of winter precipitation, spring dry period, summer precipitation, and fall dry period. The spring dry period (May - June) has higher temp and the greatest influence on the plant and animal community (Lowe 1976).

Sellers (1960) divided the state into homogeneous sections with respect to climate, topography, and vegetation. From the southwest section (the area of importance in this study) to the plateau section there are extreme changes in climatic conditions. The plateau section has an average annual temp 20 to 25° F lower and annual precipitation 38 to 51 cm higher than the flat deserts of the southwest section. The southwest section contains the lowest, hottest and driest areas of the state (Sellers 1960).

Of the 6 life-zones in Arizona, only the Lower Sonoran, containing portions of the Sonoran, Mojave and Chihuahuan Desert (Fig. 1), was important to this study. The Sonoran Desert has 2 subdivisions in Arizona — the Lower Colorado and Arizona Upland subdivisions (Fig. 1). The Lower Colorado subdivision (ele-

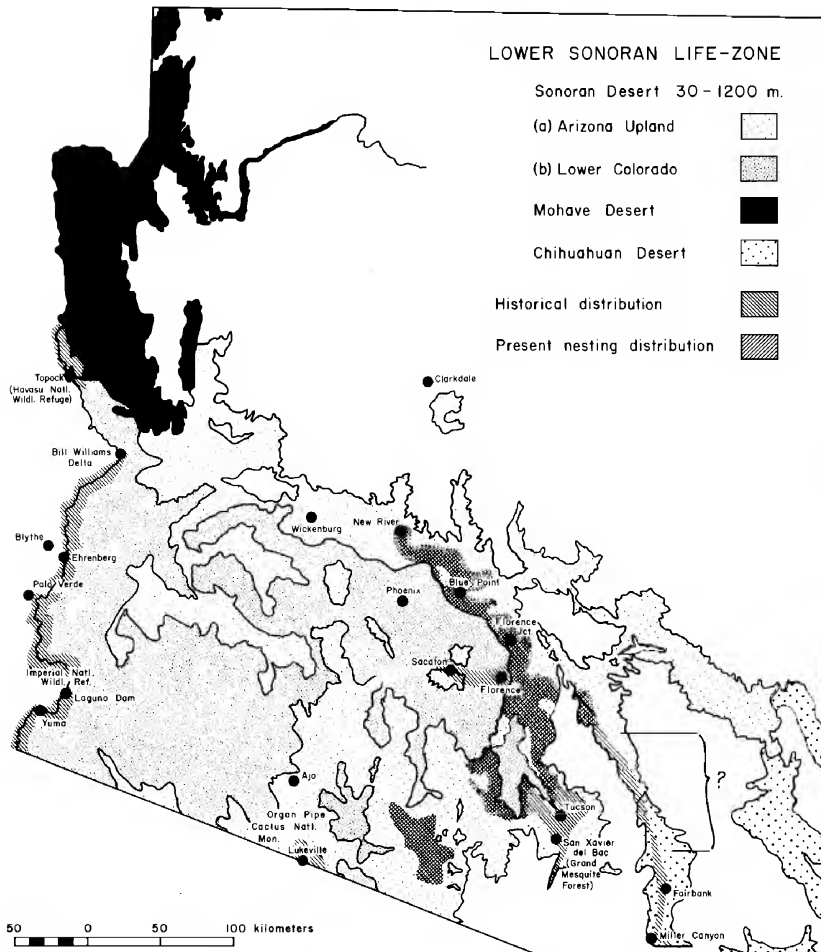


Figure 1. Map of the historical and present distribution of the Harris' Hawk in Arizona in relation to vegetational zones.

vation 30-90 m) is primarily a creosote bush-bursage (*Larrea-Franseria*) community and includes the hottest and most arid regions in Arizona. This subdivision is characterized by sandy and gravelly plains and mesas, sand dunes, lava flows, silty valleys, salt basins, rocky hills, and desert pavement. The Arizona Upland subdivision (elevation 150-1220 m) is typified by a paloverde-saguaro cactus (*Cercidium-Cereus*) association. It attains greatest development on the rocky soils of desert mountain slopes and on the coarse soils of upper bajadas that flank mountain ranges. The Arizona Upland subdivision has far greater numbers of plant species than the Lower Colorado subdivision.

The Mojave Desert (elevation 240-1580 m) scarcely reaches into northwestern Arizona. The higher aridity, lack of summer rains and longer periods of below freezing winter temp cause this desert to be poorer in plant and animal life than the Sonoran Desert (Lowe and Brown 1973).

The Chihuahuan Desert enters Arizona in a small southeastern section of the state, where it lies mostly above an elevation of 1070 m. This relatively complex desert is essentially shrubby with many grasses, several small species of cacti, and few desert trees.

Field work was conducted in 1976 and 1977 from January through October of each year. The Harris' Hawk in Arizona has never been observed nesting outside the Lower Sonoran Life-zone, so I eliminated the northern half of the state from the survey. After a broad general search of the Lower Colorado subdivision, I determined that the Arizona Upland subdivision was the most important area to nesting Harris' Hawks. Hills, windmill towers, and other elevated points were used to locate nests. In flat country I used an 8.5 m extension ladder mounted on the bed and cab of a pickup truck which allowed visual clearance above the vegetation.

All nest sites were plotted on USGS 1:250,000 topographic

quadrangles and series maps. Throughout the population continuum there were local concentration points and from 2 of these populous areas I attempted to find all active nests to determine total nesting density. The mean distance between nests was determined by measuring the distance from each nest and its nearest neighbor using the distance between any 2 nests only once. By halving the mean distance, a value  $r$  (radius) was obtained and used to determine average nesting range size by the formula  $A = r^2$  under the assumption that nesting ranges were circular. I used only those nesting ranges that were active in a given year.

Each nest was visited a minimum of twice in order to determine number of eggs laid and number of young fledged (in 1976 nests were visited 3 to 5 times). When a clutch appeared small or incomplete, a later visit was scheduled in order to obtain data for full clutch size. Young were aged by comparison with color photographs of known age birds taken at 5 d intervals.

## RESULTS

### Distribution and Habitat Characteristics

**Past Populations.** — Historically, there were 2 localized populations of Harris' Hawk in Arizona. One population was resident in western Arizona in Lower Colorado habitat along the Colorado River from Yuma northward to Topock (Fig. 1). The Lower Colorado population was extirpated by 1969. A second population approximately 280 km eastward in Arizona Upland habitat (Fig. 1) remains today. The 2 localities are separated by a dry, barren expanse of the Lower Colorado Desert.

The earliest record for Harris' Hawk in Arizona was reported near Topock by Kennerly (1859). The Lower Colorado population likely originated from Baja California, extending its range into the United States along suitable segments of the Colorado River (Fig. 1). Along the river, nesting sites were near small lakes, lagoons and swamps in flooded mesquite and in willow and cottonwood trees (Wiley 1916, 1917; Bancroft 1920; Rowley 1936). Prey items included the Purple Gallinule (*Porphyrio martinica*), Sora (*Porzana carolina*), Common Teal (*Anas cyanoptera*), and Northern Flicker (*Colaptes auratus*) (Miller 1925, 1930). Gale Monson (pers. comm.; past manager of Havasu Natl. Wildl. Refuge) included the American Coot (*Fulica americana*), Muskrats (*Andatra zibethicus*), Cotton Rats (*Sigmodon hispidus*), and Abert's Towhee (*Pipilo aberti*) as food found in nests. Harris' Hawks were frequently common at places along the river near Havasu National Wildlife Refuge with a resident average of 30 individual/y from 1947-59. As many as 50 individuals were often reported, and nests were sometimes less than 0.8 km apart (U.S.D.I. Fish and Wildlife Service 1952). Generally, 2

young/nest were reported with only 2 parent birds caring for them. Nests were often built on top of old Great Blue Heron (*Ardea herodias*) nests and were commonly only 3 to 5 m above water (Gale Monson pers. comm.). A population decline started in the late 1950's and by 1969 the Harris' Hawk disappeared from the refuge. A wild population has not since been observed along the Colorado River. A concurrent decline and extinction was noted at Imperial National Wildlife Refuge to the south. An extensive list of sources concerning Harris' Hawks along the Colorado River is included in Whaley (1979, Appendices A and B).

**The Present Population (1976-1977).** — The present Harris' Hawk population in Arizona occupies 3,880 km<sup>2</sup> in Arizona Upland habitat with elevations ranging from 396 to 1,036 meters ( $\bar{x}$  = 701 m). Lowe and Brown (1973) delineate prime Arizona upland habitat as the region "... east then north of a line drawn from Ajo to Tucson to Florence Junction, then northwest to Wickenburg" and the Harris' Hawk followed this distribution closely (see Fig. 1). Nearly all nests were placed in paloverde-saguaro cactus habitat or in the more local narrow strips of blue paloverde-ironwood (*Cercidium floridum-Olneya*) habitat of the large arroyos. Three exceptions were nests placed in large cottonwood trees in riparian communities that were juxtapose to the aforementioned habitat. No nests were found, nor birds seen, in riparian communities along rivers that were not associated with the Arizona Upland subdivision (Fig. 1).

### Nest Site Characteristics

Saguaro cactus was the preferred plant species used for nest sites (Table 1). Five active nests and 42 old nests were placed on electrical transmission towers along a 13.7 km section of 110 kV powerline crossing paloverde-saguaro cactus habitat. Another nest was placed on a tower along a 345 kV electrical transmission line crossing excellent Harris' Hawk habitat.

Nest height ranged from 2.3 m [foothill paloverde (*C. microphyllum*) tree] to 21.3 m (electrical transmission tower). The average height for nests in saguaro cacti, blue paloverde trees, and foothill paloverde trees was 5.8 m, 6.3 m and 4.4 m, respectively. Seventy-two percent of all nests were placed in mature saguaro  $\geq 4.9$  m tall with substantial arms.

Table 1. Harris' Hawk nest sites in 1976 and 1977 in Arizona.

NEST SUPPORT	NUMBER OF NESTS	PERCENTAGE OF TOTAL
Saguaro Cactus	230	75.2
Foothill Paloverde	37	12.1
Blue Paloverde	23	7.5
Electrical Tower	6	2.0
Cottonwood	3	1.0
Ironwood	3	1.0
Mesquite	2	.6
Pine	1	.3
Palm	1	.3
Totals	306	100.0

### Breeding Season Phenology

**Courtship.** — Courtship behavior of Harris' Hawks is typical of most raptors (Brown and Amadon 1968), but on 18 February 1977 I noted a very unusual "group courtship" display involving 8 adults. The adults flying at an altitude of 150-180 m, continually engaged in soaring, tail chasing, and stooping, accompanied by much vocalizing. The long vertical stoops, which often involved all 8 hawks, were followed by tail chasing and eventual return to their former altitude where the event was repeated. Similar behavior has been reported for Eleonora's Falcon (*Falco eleonorae*) when near the breeding cliffs (Brown and Amadon 1968) but is apparently rare in falconiforms. The observed behavior lasted approximately 45 min, when the adults departed in 3 directions. Later, an active nest was found in each of the 3 areas where the respective groups appeared to have flown. At 2 of these nests, 3 adults were present.

Copulations occurred over a 6-month period from 28 January to 26 July. Each copulation bout lasted from 15 to 40 sec. ( $X = 24$  sec,  $N = 23$ ). Courtship behavior did not always precede mating; on several occasions I witnessed copulations in which a male flew directly to a female and copulated without obvious display by either sex. More than 1 adult males were observed at many of the nest sites; 2 males were recorded at 41% and 3 at 5% of 227

active nesting ranges. On 11 February 1977, I observed 7 copulations in 2 h, involving a female and both males at a territory near Florence Junction. Polyandrous mating behavior has been previously reported for this species (Mader 1975a).

**Nest Construction.** — Harris' Hawks build or repair nests from January to August. Often one of several alternate nests is repaired or pairs may use the same nest several times in succession. Several nests may be repaired and 1 chosen for use. In 1 territory 8 nests were located, one of which had been repaired and was ready for eggs on 10 February 1977 (copulation observed on 28 January 1977). Materials are continually added to nests while eggs and nestlings are present.

**Timing of Incubation, Hatching, Fledging.** — Using a 35-d incubation period and a 45-d nestling period (Mader 1975b), I determined the time spans for beginning of incubation, for hatching and for fledging of young (Fig. 2). Eggs were laid from mid-January to mid-August. Fifty percent of all first clutches ( $N = 284$ ) were laid between 20 February and 22 March (Fig. 2). A portion of clutches laid during and after April were second clutches for the given year (Fig. 2).

Double or triple clutches occurred 61 times involving 50 (21.6%) of the nests studied; 39 (63.9%) followed a successful first attempt, and 22 (36.1%) followed an unsuccessful first nesting attempt ( $X^2 = P < .05$ ). Of those following a successful brood, the time interval between first and second clutches averaged 106 d. Within 8 nesting ranges the short interval between clutches ( $\bar{x} = 75$  d) indicated that eggs were laid before the first young had fledged. This was confirmed within 2 nesting ranges. Within one, 2 eggs were laid in the same nest with a 23 to 25 d old chick. In Texas the time interval from fledging of the first attempt to completion of the next clutch was 28 d (range 7-59 d) for 6 second attempts (Brannon 1980).

January egg laying was documented only once during the study period (eggs laid mid-January 1976). On 12 February 1977 another nest containing 3 eggs was found which may have been started in January, but egg-laying or incubation date could not be determined since the eggs never hatched. Whenever pairs commenced laying of the first clutch early in the year, 3 clutches/breeding season were laid during both 1976 and 1977.

Hatching dates for 284 clutches spanned 8 months (mode = April) and fledging dates spanned



7 mo (mode = May) (Fig. 2). The latest fledging date was near 28 October. An extremely late fledging date of 8 November has been reported for Harris' Hawks in Texas (Brannon 1980).

### Nesting Density and Territorial Fidelity

Nesting density of Harris' Hawks in Arizona was 1 nest/2.5 km<sup>2</sup> in 1977 for both Study Areas A and B (Fig. 3). The mean distance between nests in both study areas was 1.8 km. At 9 locations active nests were only 0.8 km apart, and at 2 locations active nests were just 0.5 km apart. As a result of the observed close nesting patterns, I expect that territories overlap.

Territorial attachment seems strongly developed. Eighty-four percent of 123 active territories occupied in 1976 were reoccupied and active in 1977. Another 9 territories occupied in 1976 had adults present in 1977 but active nests were not found. On this basis, Harris' Hawks reoccupied 91% of 123 nesting territories used in 1976. Mader (1982) found that the Savanna Hawk (*Buteogallus meridionalis*) also has strong territorial attachment from year to year.

Eight nests used by Harris' Hawks in 1976 were used by Great Horned Owl (*Bubo virginianus*) (N =

7) and Red-tailed Hawk (*Buteo jamaicensis*) in 1977 and appeared to have little influence on Harris' Hawks reoccupancy of old territory. The Red-tailed Hawk usurpation resulted in the Harris' Hawks locating a new nest 160 m from their 1976 site.

### Productivity

I recorded a total of 396 nesting attempts (including second and third clutches) involving 306 nests within 231 active nesting ranges. In order to compare productivity with that from other studies (Mader 1975b; Griffin 1975; Griffin 1976; Brannon 1980), a successful nest was one in which a nestling reached the age of at least 28 d. Of 319 nesting attempts, 72% were successful. Seventy-seven nests had incomplete data. Seventy-five nests failed during the egg laying and incubation period. Fifteen nests failed during the nestling period (2 were man-caused, 2 were caused by inclement weather, and cause of failure could not be determined for 11).

Mean clutch size in 1976 was 3.04 (N = 67) and 3.22 (N = 95) in 1977 with a combined mean of 3.16 (N = 162) (clutch size/number of clutches: 1/4, 2/29, 3/73, 4/51, 5/5) for the study period. Number

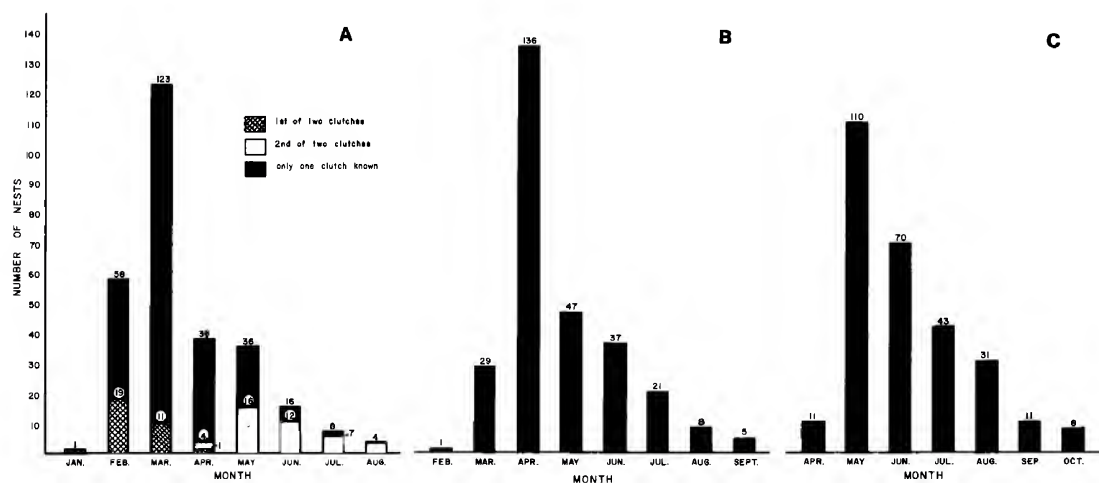


Figure 2. Number of nests in relation to (A) month when incubation begins, (B) month of hatching and (C) month of fledging for 284 Harris' Hawk nesting attempts in Arizona in 1976 and 1977.

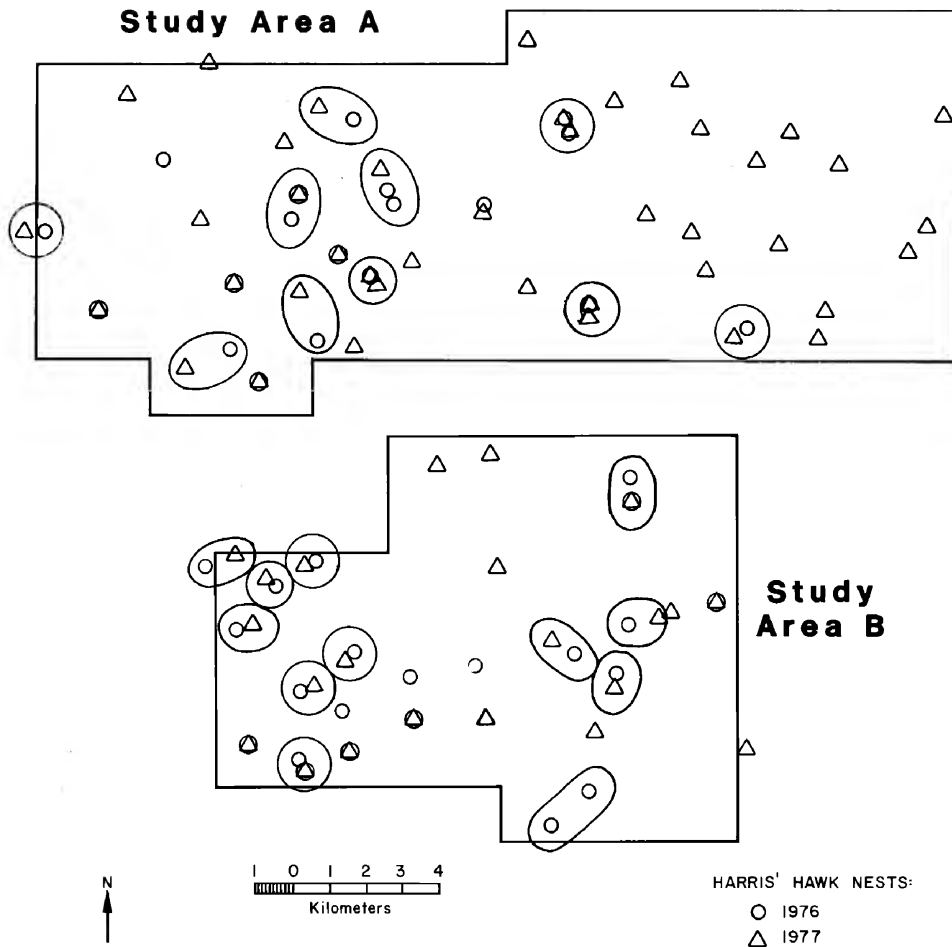


Figure 3. Proximity of Harris' Hawk nests in Study Area A (230 km<sup>2</sup>), containing 39 nesting ranges with 51 active nests, and in Study Area B (135 km<sup>2</sup>), containing 26 nesting ranges with 38 active nests. Large circles containing > 1 symbol indicate 1 nesting range and are not intended to delineate the size of a range.

of fledglings/nest ranged from 1 to 4 (number fledglings/number broods: 1/59, 2/75, 3/71, 4/24) and averaged 1.62 young/all attempts (Table 2).

I calculated productivity using the more complete data of 71 nesting attempts of 1976 and compared these values with productivity obtained when using the less complete, but larger sample size, of the foregoing. Using only the 1976 data, "hatching" and fledging success were calculated (Table 3). Values obtained for "mean clutch size" and "young fledged/all attempts" were similar to the corresponding values from the larger sample. There was

a 51% loss in productivity between egg laying and fledging, most resulting from eggs failing to hatch (41%, Table 3). Egg loss was recorded for 89 nests, 42% due to nest failure (loss of complete clutches) and 58% due to partial hatching of clutches. A Texas population had a 41% productivity loss (Brannon 1980). At least 612 young fledged during the study period. Two hundred twelve nestlings were banded in 1977. Sex ratio of nestlings was 1.2 ♂♂: 1.0 ♀♀.

Harris' Hawks in sub-adult plumage were found to breed occasionally. Ten sub-adults within 6 ter-

Table 2. Harris' Hawk nesting success in Arizona, 1976 and 1977.

	TOTAL NUMBER OF NESTING ATTEMPTS	NUMBER OF SUCCESSFUL NESTS <sup>1</sup>	NUMBER OF YOUNG	YOUNG FLEDGED PER ALL ATTEMPTS	YOUNG FLEDGED PER SUCCESSFUL ATTEMPTS
1976	143	102 (71%)	229	1.60	2.25
1977	176	127 (72%)	289	1.64	2.28
Total nests and young	319	229 (72%)	518	1.62	2.26

<sup>1</sup>A nest was considered successful if a chick was raised to an age of at least 28 days. Only nests where adequate fledging data was obtained appear in the table.

ritories succeeded in raising 7 young. In each case the female was a sub-adult. In 3 territories all hawks were sub-adults.

#### Mortality Factors

Hatching success (59%, Table 3) indicates a high egg loss. Laying of infertile eggs, nest abandonment and destruction by predators contributed to reduced hatching success. Infertility appeared to be the most common cause (e.g., one pair laid 4 eggs in both 1976 and 1977; incubation times were 65 and 73 d, respectively, with no hatching and no embryo development in both years). Forty-seven young died or disappeared from nests during the 2-y period (7 young were taken by man, 5 were killed by man, 5 died of disease, 2 died when a cactus containing a nest fell, and 1 died when it fell from its nest). Cause of death of 27 young could not be determined. Other mortality factors for adults and fledglings were electrocutions (8 cases reported), and accidental trapping of Harris' Hawks by coyote trappers.

In 1976 a resident of Owl Head Ranch near Tucson stated that he found a dead Harris' Hawk and other birds floating in the metal livestock water tanks on his ranch. In July 1978 a dead juvenile female Harris' Hawk was found floating in a large livestock water tank (Larry Livingston pers. comm.) not far from where it was banded as a nestling in May 1977. Drowning deaths may be a significant cause of mortality, especially during the dry period (May-June) when livestock tanks are the only available source for drinking and bathing. Drownings in water tanks have been documented for the Prairie Falcon (*Falco mexicanus*) (Enderson 1964), Ameri-

can Kestrel (*Falco sparverius*) (Craig and Powers 1976) and Ferruginous Hawk (*Buteo regalis*) (Clayton White pers. comm.).

Cholla cactus (*Opuntia* sp.) may also cause mortality in Harris' Hawks. On 26 May 1976 I found a recently fledged Harris' Hawk partially immobilized (could not fly and could hardly walk) on the ground near its nest. Cholla cactus joints were stuck on its neck and between its legs. On another occasion I chased down and caught an older fledgling that was having difficulty flying and

Table 3. Summary of productivity data for 71 Harris' Hawk nesting attempts in Arizona in 1976.

	RESULTS	RANGE
Mean clutch size	3.07	1 - 5
Young fledged per all attempts	1.63	0 - 4
Young fledged per successful attempt	2.18	1 - 4
Percent hatching success	59	41% productivity loss (eggs failed to hatch)
Percent fledging success	90	10% productivity loss (young failed to fledge)
Percent successful nesting attempts	75	
Percent unsuccessful nesting attempts	25	

keeping its balance when landing. The bird was obviously weakened. I found 2 cholla cactus joints clasped in its feet such that it could not release its

grip. Survival of a raptor in such condition is questionable since food would be difficult or impossible to obtain.

Table 4. Prey items observed at nests of Harris' Hawks in Arizona in 1976 and 1977.

SPECIES	NUMBER OF ITEMS	PERCENTAGE OF TOTAL
Mammals:		
Cottontail Rabbit <i>Sylvilagus audubonii</i>	144	22.4
Harris' Ground Squirrel <i>Citellus harrisi</i>	79	12.3
White-throated Woodrat <i>Neotoma albigula</i>	76	11.8
Black-tailed Jackrabbit <i>Lepus californicus</i>	9	1.4
Round-tailed Ground Squirrel <i>Citellus tereticaudus</i>	5	0.8
Pocket Gopher <i>Thomomys bottae</i>	2	0.3
Merriam's Kangaroo Rat <i>Dipodomys merriami</i>	1	0.2
Banner-tailed Kangaroo Rat <i>D. spectabilis</i>	1	0.2
Arizona Pocket Mouse <i>Perognathus amplus</i>	1	0.2
Unidentified Lagomorphs	65	10.1
Unidentified Kangaroo Rats	4	0.6
Unidentified Ground Squirrels	3	0.5
Unidentified Mice	2	0.3
Total Mammals	392	61.1
Birds:		
Gambel's Quail <i>Callipepla gambelii</i>	56	8.7
Cactus Wren <i>Campylorhynchus brunneicapillus</i>	42	6.5
Screech Owl <i>Otus kennicottii</i>	14	2.2
Northern Flicker <i>Colaptes auratus</i>	13	2.0

(Table 4 continued)



(Table 4 continued)

SPECIES	NUMBER OF ITEMS	PERCENTAGE OF TOTAL
Elf Owl <i>Micrathene whitneyi</i>	8	1.2
Mourning Dove <i>Zenaida macroura</i>	6	0.9
Curve-billed Thrasher <i>Toxostoma curvirostre</i>	4	0.6
Gila Woodpecker <i>Melanerpes uropygialis</i>	3	0.5
Road Runner <i>Geococcyx californianus</i>	2	0.3
American Kestrel <i>Falco sparverius</i>	1	0.2
Cooper's Hawk <i>Accipiter cooperii</i>	1	0.2
Unidentified Thrashers	12	1.9
Unidentified Doves	5	0.8
Unidentified Birds	12	1.9
Total Birds	179	27.9
Reptiles:		
Desert Spiny Lizard <i>Sceloporus magister</i>	63	9.8
Regal Horned Lizard <i>Phrynosoma solare</i>	2	0.3
Zebra-tailed Lizard <i>Callisaurus draconoides</i>	1	0.2
Western Whiptail Lizard <i>Cnemidophorus tigris</i>	1	0.2
Leopard Lizard <i>Crotaphytus wislizeni</i>	1	0.2
Unidentified Reptiles	2	0.3
Total Reptiles	70	11.0
Total Number of Prey Items	641	100.0

## Food Habits

A quantitative analysis of food habits in Harris' Hawks was not possible during this study because of time restraints imposed by the large number of nests being observed. Often the only sign of occurrence of an avian prey species was the presence of feathers which denoted little or nothing of the number of individuals taken. Thus I could only indicate that a particular species was found. Since certain body parts of larger mammals (i.e., hind feet of Cottontail Rabbits [*Sylvilagus audubonii*] and tails of Harris' Ground Squirrels [*Citellus harrisi*]) were not eaten and remained in the nest for long periods of time, a more accurate figure for the number of these species taken could be obtained. The food data presented represents a qualitative study of the entire population, which may provide some idea of the total gamut of prey species taken throughout the Harris' Hawk population in Arizona.

Harris' Hawks are quite catholic in feeding habits. Twenty-five vertebrate species were recorded (Table 4), of which 61.1% were mammals. Brannon (1980) found 65.6% of Harris' Hawk prey in Texas to be mammals. Cottontail Rabbit appear to be important in the diet, carcasses at times covering the entire tops of nests. At one nest, pairs of hind feet indicated that at least 22 lagomorphs had been taken. Harris' Ground Squirrels, White-throated Woodrats (*Neotoma albigula*), Gambel's Quail (*Callipepla gambelii*), and Cactus Wrens (*Campylorhynchus brunneicapillus*) also appear to be important in Harris' Hawk diets in Arizona. Four raptors, Screech Owl (*Otus kennicottii*), Elf Owl (*Micrathene whitneyi*), Coopers' Hawk (*Accipiter cooperii*), and American Kestrel (*Falco sparverius*) were taken.

## DISCUSSION

### Phenology of the Breeding Season

Harris' Hawks in Arizona may lay eggs as early as January (Ellis and Whaley 1979) and sometimes fledge young as late as December (Radke and Klimosewski 1977) which gives them the distinction of having the longest known "breeding season" (as defined by Moreau 1950) of any temperate North American falconiform. In Sonora, Mexico (27° N°), eggs are even laid in November (Ellis and Whaley 1979), suggesting that there are continuous breeders in some southern parts of the Sonora Desert.

The terminology "continuous breeder" follows Immelmann's (1971) definition that within a population eggs are laid during every month of the year. This is not the case (as currently known) in the Arizona population since no egg laying has been recorded for the period October-December.

Lack (1968) and Immelmann (1971) suggested that, since the reproductive period is the most rigorous and critical period of a bird's annual cycle, it is imperative that it be scheduled at a time when young can most profitably be raised with a minimum of energy expenditure on the part of the adults. A good example, Eleonora's Falcon of the Mediterranean region, delays breeding until August when it can feed its young on the numerous passerines in fall migration (Walter 1979). Eleonora's Falcons feed mainly on insects during the remainder of the year.

Harris' Hawks seem to follow a similar pattern, as they breed during periods of great prey abundance. Breeding starts quite early in Arizona. Incubation begins in February and March and hatching occurs primarily in April (Fig. 2). Prey species also exhibit long breeding seasons in Arizona. Harris' Ground Squirrel breeds from late February to May with its conception period running from 31 March to late May (Neal 1965). On this basis, Harris' Ground Squirrels are being born when the majority of Harris' Hawk eggs are hatching. Cottontail Rabbits breed year-round in Arizona with peaks for conception starting in April (peak hatch time for Harris' Hawks) and running through July (Hungerford, Lowe and Madsen 1973). The White-throated Woodrat has successive litters from January to August (Vorhies and Taylor 1940), which spans the time during which most Harris' Hawks are breeding. Thus, local abundance and long breeding seasons of prey species may be an important facilitatory factor for an extended breeding season of Harris' Hawks in southern Arizona.

Several other prey species that have long breeding seasons are Gambel's Quail (March to September, Bent 1932), Cactus Wrens (raise 3 broods from February to August, Anderson and Anderson 1960), Curve-billed Thrasher (*Toxostoma curvirostre*) (February to July, Smith 1971), and Mourning Dove (*Zenaida macroura*) (March to September, Brown 1967). The Harris' Hawk's catholic prey habits on species with long reproductive periods may have contributed to the development of an

extended breeding season and increased productivity through double brooding.

When the environment permits a species to raise > 1 brood/yr, breeding begins as early as possible even though the timing of the first attempt may be less favorable (Lack 1968). A species using this strategy would tend to produce the maximum number of offspring under the prevailing circumstances (Lack 1954). Harris' Hawks may follow this strategy, as second and third breeding attempts appear to be influenced by an early first attempt (Fig. 2). The outcome (i.e., success or failure) of the first breeding attempt appears to be less important than timing. Of females that laid double and triple clutches, 97% of the first breeding attempts were started before April, the majority beginning in February. The only January laying represented the first of 3 clutches produced in 1976 by a trio of adults which fledged 5 young from two of the three attempts. Without subsequent nesting, their productivity for 1976 would have been just 2 young. Within 6 other territories high productivity was attained through extra breeding attempts. Adults in 4 territories produced 6 and those in 2 territories produced 7 young/yr. Most of the clutches laid from June to August were second and third attempts (Fig. 2). An early laying pair of Harris' Hawks in Texas produced 7 young during 3 successful nesting attempts in one season (Brannon 1980). Triple clutches in 1 season have been reported 3 times previously for Harris' Hawks (Mader 1977; Whaley 1979), but in all cases only 2 of the 3 attempts were successful. Harris' Hawks begin egg laying earlier in Arizona than in Texas (see Brannon 1980), where clutches are started in March and April.

### Productivity

**Clutch Size.** — Mean clutch size for Harris' Hawk populations in this study was 3.16 ( $N = 162$ ) with 4 and 5 eggs/clutch regularly laid. Four eggs/clutch are not uncommon for Harris' Hawks in Texas (Griffin 1976) and Arizona (this study) whereas along the Colorado River 2 eggs/clutch are the rule (Bendire 1892). Mader (1975b) obtained an average of 2.96 eggs/clutch ( $N = 50$ ) for Arizona, and Griffin (1976) calculated an average of 2.85 eggs/clutch ( $N = 20$ ) for western Texas. South Texas populations appear to have a smaller clutch size of 2.33 eggs/clutch ( $N = 24$ ) (Brannon 1980). Some females in my study were exceptional egg layers; 3

females each laid 16 eggs during the 2-yr period. One of these laid 4 clutches of 4 eggs, all but one of which was in the same nest.

**Fledging Rate.** — Productivity of Harris' Hawks in Texas is lower than for Arizona and New Mexico populations. Mader (1975) found that 1.60 young fledged/all attempts ( $N = 50$ ) and 2.35 fledged/successful attempts ( $N = 34$ ), which compares well with my results for Arizona (Table 2). Griffin (1975) reported similar results for New Mexico, with 1.59 ( $N = 17$ ) and 2.45 ( $N = 11$ ) young/attempt and young/successful attempt, respectively. Griffin (1976) reported values of 0.83 ( $N = 18$ ) and 1.87 ( $N = 8$ ) young/attempt and young/successful attempt, respectively, for western Texas. Brannon (1980) reported similar results of 1.37 ( $N = 24$ ) and 2.06 ( $N = 16$ ) for young/attempt and young/successful attempt for west Texas populations. Lower productivity in Texas populations is likely due to greater fluctuations in prey abundance (Griffin 1976) and less diversity in prey species. Texas populations are more nomadic, as year to year shifts in breeding distributions occur in accordance with rainfall patterns and prey abundance.

### Dispersal of Young and Nest Helping

Harris' Hawks in Arizona are nonmigratory. Early reports of large migratory flocks (250 to 500) (Chambers 1921 and 1924; Allan Phillips pers. comm.) are unreliable, and likely the result of misidentification since Harris' Hawks in Arizona have a long breeding season which affords no time for migration.

Harris' Hawks occasionally wander during winter, but generally remain near or within their nesting ranges year round. Families often remained together. On 2 occasions I saw winter groups of 7 and 8 hawks comprised of adults and color-marked juveniles. Wilder (1916) also noted large winter groups of 10 to 20 hawks along the Colorado River in December.

Juveniles do not exhibit a strong tendency to disperse from the natal area. On 10 November 1977 two color-marked Harris' Hawks were trapped less than 0.4 km from where they fledged ca. 173 days earlier (Rich Glinski pers. comm.). On 9 occasions within those 1977 nesting ranges where nesting occurred twice in 1 year, color-marked juveniles of earlier nesting attempts were allowed within the immediate vicinity of, and often on the nest containing eggs or young of subsequent nest-

ing attempts. Those juveniles often seemed as concerned about my presence as the adults. On 22 occasions in 1976 unmarked juveniles which were likely still in natal ranges were sighted near active nests.

On 24 September 1977, while preparing to band 3 young from a second nesting (the first brood of 3 young fledged ca 120 d earlier), a color-marked female from the first brood brought prey to the nest. Also, on 3 occasions in 1979 Brannon (1980) observed prey deliveries by juveniles to the nests of their parents' second breeding attempts. On 12 May 1977 two juveniles that had fledged 2 or 3 weeks earlier were observed incubating 3 eggs of their parents' second clutch. Nest-helping by juveniles fledged earlier the same season has not been previously reported in raptors. The helper system of the Harris' Hawk may prove to be similar to that of the Florida Scrub Jay (*Aphelocoma coerulescens*) (Woolfenden 1975). Young of Galapagos Hawk (*Buteo galapagoensis*) also remain near the natal area for several months after fledging and occasionally retain close ties with their parents (de Vries 1973). On 1 occasion de Vries witnessed a 5-month-old juvenile still begging food from the male parent while the female was incubating eggs of a second nesting attempt.

Harris' Hawks do not appear to disperse great distances from their natal area over long periods of time. Based on 13 band returns, sightings and capture-releases, juveniles ( $\geq 5$  months fledged) traveled an average distance of 15 miles (range  $< 5$  miles for a male during 3 years and 30 miles for a female during 6 months). On 20 May 1977 I banded a male nestling near Florence Junction. The same male was trapped in its nesting territory nearly 8 yrs later on 12 January 1985 (Jim Dawson pers. comm.) 35 miles south of where it had fledged.

### Past Populations of the Colorado River

The Harris' Hawk was a common resident along the Colorado River for at least 134 years. The population did not range far from the riparian community (U.S.D.I. Fish and Wildlife Service 1950); thus, events that may have affected this habitat may also have impacted the Harris' Hawk populations in that region. Extensive flooding along the Colorado River in the early 1900's evoked construction of several dams in the 1930's and

1940's. With flooding controlled, agricultural activities along the river increased. By the 1930's and 1940's, salt cedar (*Tamarix pentandra*) spread over large areas of the river and began to compete with the cottonwood community which was rejuvenating from past floods. Dredging operations began along the river during the 1940's and may have been a source of disturbance. Previously inaccessible areas of the swamp were now accessible by motor powered craft so subsequently there was increased use of the river for recreational activities during the 1950's (Gale Monson pers. comm.). At Havasu National Wildlife Refuge, where Harris' Hawks often nested low over the water in drowned out mesquite trees, increased recreational activities may have been a major factor during the nesting periods. Fishermen were seen destroying nests, probably under the mistaken impression of destroying Cormorant (*Phalacrocorax* sp.) nests (Gale Monson pers. comm.). Harris' Hawks were occasionally harassed by duck hunters who often referred to them as, "the big black hawk that catches ducks" (Miller 1925). Monson reported that Harris' Hawk numbers were sometimes slightly depleted by waterfowl hunters in the open areas above Topock (U.S.D.I. Fish and Wildlife Service 1949).

A combination of the above factors likely had an impact on Harris' Hawk populations along the Colorado River. Drastic habitat alteration and increased recreational activities perhaps yielded the greatest impact.

### The Present Population

Qualitatively, the most obvious characteristic of Harris' Hawk habitat in Arizona is the presence of healthy stands of paloverde-saguaro desert scrub of the Arizona Upland subdivision. The present distribution of Harris' Hawks in Arizona strictly follows the Arizona Upland subdivision of the Sonoran Desert with no nests occurring outside this habitat. Thus, this hawk habituates the most structurally complex habitats within the Sonoran Desert, where prey density and diversity is the greatest.

The nesting distribution of the Harris' Hawk in Arizona has shrunk since the early 1900's due in part to the extirpation of populations along the Colorado, Gila, Santa Cruz, and San Pedro Rivers. Along the Gila and Santa Cruz habitat has been severely altered (Dawson 1921; Rea 1977). In order to determine susceptibility of the present popula-



Table 5. Land ownership status for 306 nest sites and 396 nesting attempts for Harris' Hawk in Arizona in 1976 and 1977.

LAND OWNERSHIP	NUMBER OF ACTIVE NESTS	PERCENTAGE OF TOTAL	NUMBER OF NESTING ATTEMPTS	PERCENTAGE OF TOTAL
State Trust Land	140	45.8	184	46.5
Patented Land	73	23.9	84	21.2
BLM Land	40	13.0	57	14.4
Forest Service	18	5.9	24	6.0
Indian Reservation	18	5.9	23	5.8
Patented or State	7	2.3	10	2.5
BLM or State	5	1.6	8	2.0
Regional Park	3	.9	3	.8
U.S. Park	2	.7	3	.8
Totals	306	100.0	396	100.0

tion to possible habitat encroachment, I determined land ownership status for 306 active nest sites (Table 5). A large proportion of nests are on patented land, and therefore are more vulnerable to the effects of man's present and future activities. Since the Harris' Hawk appears to be habitat restricted in its nesting, the retention of both state and federal lands with healthy stands of paloverde-saguaro will be crucial for its future welfare in Arizona. Urban sprawl near several Harris' Hawk populations may result in continued loss of nesting range in Arizona. Harris' Hawk numbers near Tucson and Cave Creek have declined recently as a result of urban development. The Cave Creek population is currently threatened due to urban sprawl and may soon be decimated (Jim Dawson pers. comm.). Other habitats that are threatened by urban development are in areas near Rio Verde, Apache Junction, and Florence.

#### ACKNOWLEDGMENTS

Research was conducted as part of the M.S. degree requirements at the Arizona Cooperative Wildlife Research Unit (ACWRU) of the University of Arizona. The ACWRU is sponsored jointly by the University of Arizona, the U.S. Fish and Wildlife Service, the Arizona Game and Fish Department, and the Wildlife Management Institute.

I thank Lyle K. SOWLS, leader of the Arizona Cooperative Wildlife Research Unit, for his guidance throughout this project. I also

thank other members of my committee, David H. Ellis and Stephen M. Russell, for their guidance. I express appreciation to my field assistants, Jerry Roberts, Greg Depner and Kevin Coates, for their determination when things got rough. I thank the Havasu National Wildlife Refuge and Imperial National Wildlife Refuge for access to their files. Several Arizona falconers and private individuals provided field assistance, for which I express appreciation. Eleanor Radke provided some color-marking material and banding assistance.

I am especially indebted to my wife, Connie, for her patience during my extended absences while gathering field data.

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Received 25 April 1985; Accepted 15 August 1985

# CRYOPRESERVATION OF PEREGRINE FALCON SEMEN AND POST-THAW DIALYSIS TO REMOVE GLYCEROL

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**ABSTRACT** — Peregrine Falcon (*Falco peregrinus*) semen was found to have a mean ejaculate volume, sperm concentration and initial sperm motility of 95  $\mu$ l,  $47 \times 10^6$  sperm/ml and 70%, respectively. When frozen in a medium containing 0.3, 0.9 or 1.48 M glycerol, post-thaw sperm motility was 29, 47 and 54%. Because of the contraceptive effect of glycerol, a dialysis procedure was developed to remove the cryoprotectant from post-thaw semen. Percent motility during post-thaw incubation was greater in samples from which glycerol had been removed by dialysis than in controls ( $P < 0.05$ ). Of 6 eggs from a single ♀ American Kestrel (*Falco sparverius*) obtained after insemination with frozen-thawed, dialyzed peregrine semen, 2 were fertile and survived to pip. One interspecific hybrid was hatched and raised successfully.

Captive breeding has been used effectively for the conservation of birds of prey for many years. Artificial insemination has been a useful technique in captive breeding programs since the early 1970's (Weaver 1983). However, there are many situations in which the efficiency of a breeding program may be reduced because semen is not available at the time or place where it is needed. The ability to freeze raptor semen would facilitate captive breeding under these and other circumstances. The ability to freeze semen also would permit banking germ plasm from rare or endangered species.

At present, a limiting factor in the use of frozen semen in domestic avian species is the inhibition of fertility by the cryoprotectant in the medium (Brown and Graham 1971; Lake and Stewart 1978; Sexton 1979; Lake et al. 1980; Lake et al. 1981; Graham et al. 1982). In order to overcome this problem, cryoprotectants such as glycerol or dimethylsulfoxide (DMSO) must be removed post-thaw (Lake and Stewart 1978; Lake et al. 1981; Graham et al. 1982) or new, less problematic cryoprotectants must be identified.

The purpose of this study was to develop procedures for processing and freezing raptor semen, using the Peregrine Falcon (*Falco peregrinus*) as a semen source; and to develop a procedure for removing the cryoprotectant glycerol from thawed semen without further loss of sperm viability.

## MATERIALS AND METHODS

**Semen Collection and Handling.** — Semen from 3 adult male Peregrine Falcons was collected up to 2 times/d (Boyd and Schwartz 1983) over a period of approximately 2 m. On each occasion, ejaculates from 1-3 ♂ were pooled. Semen was diluted 1:3 (v/v) at 20°C in 12 × 55 mm vials containing Lake's freezing diluent (Lake and Stewart 1978), placed directly into an ice water bath (0-2°C) and transported to the laboratory (see Table 1). All remaining steps up to freezing and during the thawing process were carried out at 4°C.

**Semen Evaluation.** — Sperm motility was assessed microscopically by estimating the percentage of sperm moving progressively forward (percent motility). Unfixed smears prepared from samples diluted in freezing diluent were placed on a slide warmer at 37°C for 30 sec immediately prior to evaluation. Percent motility was estimated in several microscopic fields to the nearest 5% using a phase contrast microscope at a total magnification of 400x.

Sperm concentration of the semen diluted 1:3 was determined with a hemacytometer after an additional dilution of 1:1 (v/v) in fixative (4% glutaraldehyde). Duplicate counts of each preparation were averaged for use in calculating sperm concentration of the original ejaculate.

**Semen Freezing and Storage.** — Aliquots of approximately 50  $\mu$ l of cooled, diluted semen were placed into 0.25 ml French straws (IMV) for freezing. Diluent was aspirated into the straw ahead of the semen with a small air space separating the 2 liquids. Filling the straws in this way served to seal the polyvinylchloride (PVC) plug at the end of the straw without loss of semen and also prevented straws from floating when placed in liquid nitrogen. Straws were then sealed and loaded into a Planer R204 freezer (2°C). Semen was frozen in nitrogen vapor at 6°C/min to -180°C and then plunged into liquid nitrogen (Brock et al. 1984). One straw from each freezing procedure was then thawed in water (4°C) for evaluation of percent motility. Straws were wiped dry and the semen-containing portion was emptied into precooled tubes (6 × 50 mm). Remaining straws were stored for 1-2 months prior to thawing.

Initially, semen was frozen in diluent containing 0.3, 0.9 or 1.48 M glycerol. Percent motility was estimated on aliquots prior to freezing and immediately post-thaw. Based on these initial trials using different levels of glycerol in the freezing medium (Table 2), 1.48 M glycerol was selected for routine use in subsequent experiments.

**Method for the Dialysis of Diluent and Diluted Semen.** — Dialysis to remove glycerol from the freezing medium and thawed semen was carried out using semi-micro dialysis tubing (2.55 mm diameter, molecular weight cutoff of 12,000-14,000, Spectra/Por). Tubing was washed thoroughly in twice distilled water and stored wet at 4°C prior to use. All subsequent steps in the dialysis procedures were carried out at 4°C. Tubing was tied and cut into lengths of 8-10 mm from the tied end, filled with the freezing diluent (1.48 M glycerol) and equilibrated for 10-20 min in the same diluent. Diluent was then completely removed from the tubing and 50  $\mu$ l aliquots of fresh freezing diluent or of thawed semen were pipetted into the tubing using a fire-polished 200  $\mu$ l capillary pipet and a capillary suction apparatus (Clay-Adams). The tubing was then closed with a Spectra/Por closure and dialyzed with stirring against 500 volumes of Lake's thawing medium (Lake and Stewart 1978).



Table 1. Characteristics and pre-freezing treatment of Peregrine Falcon semen.

	VOLUME FOR COLLECTION PERIOD <sup>a</sup> ( $\mu$ l)			INITIAL MOTILITY (%)	SPERM CONCENTRATION ( $\times 10^6$ /ml)	INTERVAL BETWEEN COLLECTION AND COOLING <sup>c</sup> (min)
	Individual Ejaculates	Pooled Ejaculates	All <sup>b</sup> Ejaculates			
$\bar{x}$	95.4	89.0	94.6	70.1	47.4	18.4
S.D.	51.7	38.5	49.7	6.9	16.1	6.8
Range	27-208	50-127	27-208	60-85	29-81	12-45
n	23	3	26	25	15	24

<sup>a</sup> Semen was collected between approximately 0830 - 0930 H and 1630 - 1730 H.

<sup>b</sup> Volumes for pooled ejaculates included 2 samples (partial or whole ejaculates) from 2 individuals and 1 sample from 3 individuals.

Volumes are included for individual birds from 3 collection periods in which ejaculates were pooled prior to freezing.

<sup>c</sup> Intervals were timed from collection of the last ejaculate for pooled samples. Freezing was begun within approximately 15 to 30 min after initial dilution and cooling.

#### Estimation of the Efficiency of Glycerol Removal by Dialysis. —

Removal of glycerol from the freezing medium was measured by supplementing the medium with [ $2\text{-}^3\text{H}$ ]-glycerol (New England Nuclear,  $200 \mu\text{Ci}/\mu\text{mol}$ ) at a level of  $2 \times 10^3 \text{ dpm}/50 \mu\text{l}$ . Appearance of radioactive glycerol in the dialysate relative to the initial amount placed in the dialysis tubing was used to calculate the rate and extent of glycerol removal.

Preliminary trials ( $n = 2$ ) indicated that  $>99\%$  of the glycerol in the freezing medium was removed after 30 min of dialysis. To establish the time-course relationship of glycerol removal, dialysis of freezing medium containing 1.48 M glycerol was carried out for 2 h against thawing medium containing no glycerol ( $n = 5$ ). Input samples; 0.2 ml aliquots of the dialysate taken at 0, 0.25, 0.5, 1.0, 2.0, 5.0, 15, 30, 60 and 120 min of dialysis; and residual material in the dialysis tubing were analyzed for  $^3\text{H}$  content (glycerol) by liquid scintillation spectrometry.

#### Evaluation of the Effect of Dialysis on Sperm Motility. —

Because glycerol was removed so rapidly by the dialysis procedure, damage to sperm due to osmotic effects was considered a potential problem. Therefore, dialysis conditions were established to remove the glycerol more gradually. Material to be dialyzed was transferred at 15 min intervals to thawing solutions containing glycerol decreasing in equimolar increments (1.1, 0.74 and 0.37M and no glycerol). It was assumed that the rate of glycerol equilibration (and thus removal of glycerol from the thawed semen) in these steps was approximately equivalent to that observed in the one-step procedure, and the extent of total glycerol removal was calculated on this basis. An experiment was designed to assess the effect of the step-wise dialysis procedure on falcon sperm motility during post-thaw, post-dialysis incubation. A split-ejaculate technique was used in which all treatments within each experiment were imposed on aliquots of the same ejaculate. At the

Table 2. The effect of glycerol level on pre-freeze and post-thaw motility of falcon sperm. Values are percentages.

Glycerol Level	PERCENT MOTILITY					
	PRE-FREEZE			POST-THAW		
	0.3 M	0.9 M	1.48 M	0.3 M	0.9 M	1.48 M
$\bar{x}$	75	66	70	29	47	54
S.D.	4.1	4.9	7.4	11.0	2.6	5.8
Range	70-80	60-75	60-85	20-45	45-50	45-65
n	4	6	15	4	6	15

Table 3. Post-thaw motility of falcon sperm after dialysis to remove glycerol (n = 4).<sup>a</sup> Values are percentages.

DIALYSATE	HOURS OF INCUBATION AFTER DIALYSIS					$\bar{x}^*$
	0	0.5	1.0	1.5	4.0	
1.48 M Glycerol	41	26	24	25	13	26
Four-step Procedure (1.1 M to Glycerol-Free)	43	33	35	31	20	32

<sup>a</sup> Post-thaw, pre-dialysis motility for these samples was  $55 \pm 7\%$ .

\*  $P < 0.05$

completion of dialysis, semen was emptied into tubes ( $6 \times 50$  mm) at  $4^\circ\text{C}$ . Percent sperm motility was determined immediately and after 30, 60, 90 and 240 min of post-dialysis incubation ( $38^\circ$ ).

**Artificial Insemination.** — Female peregrines were not available for testing the fertility of post-thaw, dialyzed semen. One unpaired ♀ American Kestrel (*Falco sparverius*) was inseminated with approximately 40 to 50  $\mu\text{l}$  of thawed semen, dialyzed by the step-wise procedure. Six single inseminations were made within 4 h after oviposition and the first egg laid after each insemination was artificially incubated. Thawed samples were maintained at  $4^\circ\text{C}$  until the oviduct was everted for insemination. The semen was then transferred to an insemination syringe and deposited into the oviduct (Weaver 1983). Total time between thawing and insemination including dialysis was approximately 90 min.

**Statistical Analysis.** — Means and standard deviations were calculated for semen characteristics and for motility estimates on semen diluted and frozen in different levels of glycerol. The effects of dialysis on post-thaw motility were analyzed by analysis of variance after arcsin transformation of the percentage data.

## RESULTS

Semen characteristics and information related to initial handling of semen are presented in Table 1. Semen was not scored on appearance, but only a low to moderate level of contamination by extraneous cell types and other debris was observed in the ejaculates used for freezing. Initial experiments in which glycerol was the only variable tested (Table 2) indicated that 1.48 M glycerol provided greater protection during freezing than 0.9 M or 0.3 M glycerol based on post-thaw sperm motility. However, glycerol levels were tested on separate semen collections so comparisons were not made on a statistical basis. The response to freezing, when using 0.3 M glycerol, was consistently poor; but the difference in post-thaw motility between 0.9 M and 1.48 M diluents was small, especially when ex-

pressed as the difference between pre-freeze and post-thaw motility (13 vs 16%).

Rate and extent of glycerol removal during a single step dialysis of samples are presented graphically in Fig. 1. Approximately 90% of the glycerol was removed by 15 min of dialysis, and after 30 min glycerol had been completely removed. Based on this rate of equilibration, a sample frozen in 1.48 M glycerol and dialyzed by the step-wise procedure was considered to contain less than 30 mM glycerol post-dialysis.

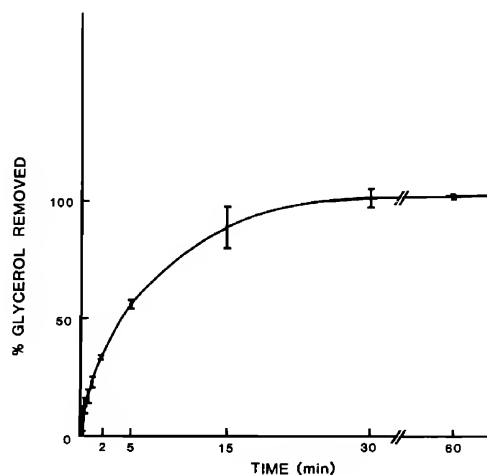


Figure 1. Removal of glycerol from semen diluent by dialysis. [ $^3\text{H}$ ]-glycerol was added to diluent containing 1.48 M glycerol and the appearance of radioactivity in the dialysate was measured. Bars represent standard deviation for each time point (n = 5).

A comparison of post-thaw motility for sperm dialyzed by the step-wise procedure or directly against the freezing medium (1.48 M glycerol) is presented in Table 3. It is apparent that sperm survived the dialysis procedure with fair to good motility. During post-dialysis incubation motility declined with both treatments ( $P < 0.01$ ). Although no significant time  $\times$  treatment interaction was found, percent motility remained sufficiently higher after glycerol removal to demonstrate an advantage over the control treatment ( $P < 0.05$ ). A consistent difference in the motility pattern was also observed between the dialysis treatments. Sperm from which glycerol had been removed exhibited a greater velocity, and motility was more progressive with less amplitude in the flagellar motion than with sperm in glycerol. This difference was not qualified but was readily apparent to other observers. Sperm in suspensions after glycerol removal also seemed more resistant to dessication on slides prepared for microscopic examination than those remaining in high glycerol medium, based on maintenance of motility.

Of 6 American Kestrel eggs potentially fertilized by frozen, thawed and dialyzed Peregrine Falcon semen, 2 eggs were fertile and developed to pip. One of these young died at pip while the other interspecific hybrid hatched and was raised successfully.

#### DISCUSSION

At present, there is very little detailed information on semen characteristics of raptorial species. This study provides such information on ejaculate volume, sperm concentration and percent motile sperm for semen from the Peregrine Falcon. Values for these characteristics have also been reported for the American Kestrel (Bird and Lague 1977). A comparison of the semen characteristics for these 2 species indicates an 8-fold greater ejaculate volume for the peregrine which approximates the difference in body weight between it and the kestrel. Sperm concentration is over 30% greater for the peregrine. The much greater total sperm/ejaculate for the peregrine may be a necessary adaptation for ensuring adequate sperm numbers at the site of fertilization in this larger species. Percent motile sperm appears to be slightly higher for the peregrine than the kestrel, but this may be due to differences in conditions under which sperm were examined. This type of information on semen

parameters is necessary for making the most effective use of artificial insemination in the species of interest, and for effective processing of semen for cryopreservation. A knowledge of semen characteristics may also serve as a basis for comparison when examining the effects of environment or environmental contamination on reproduction (Bird and Lague 1977).

In the present study, we found that peregrine semen freezes well in Lake's diluent. It appears that a broad range in glycerol level might be acceptable, but more definitive work is required to establish the optimum glycerol concentration. Brock et al. (1984) reported excellent post-thaw motility for kestrel semen frozen in Lake's diluent, but fertility of the semen was  $< 5\%$ . The requirement to remove glycerol and other cryoprotectants from post-thaw semen in order to obtain acceptable fertility has been established in domestic avian species (Brown and Graham 1971; Lake and Stewart *op. cit.*; Lake et al. 1980; Lake et al. 1981; Graham et al. *op. cit.*). This also may be true for falcon semen. Removal of glycerol from post-thaw cock semen by dilution and centrifugation greatly improves fertility (Lake and Stewart, *op. cit.*), but this approach is not practical when working with microliter quantities of falcon semen. Graham et al. (*op. cit.*) reported that the level of cryoprotectant (DMSO and ethylene glycol used in combination) necessary to maintain vigorous post-thaw motility of turkey semen depressed fertility. Use of dialysis to remove the cryoprotectant significantly improved fertility; although dialysis time, dialysate composition and pH, and semen-to-dialysate ratio all influenced the level of fertility observed. Dialysis can be adapted for use with the small semen volumes associated with raptorial species and is a milder approach for removing cryoprotectant.

Lake et al. (1980) demonstrated that in order to minimize its inhibitory effect on fertility in the Domestic Chicken (*Gallus* spp.), glycerol must be reduced to a level below 1% (0.11 M) in diluted semen. It is apparent from the present study that under the appropriate conditions glycerol can be reduced below the level of 1% within 30 min by dialysis. By controlling the sample volume/dialysate ratio or by adjusting the level of glycerol in the dialysate, rate of glycerol removal can be regulated to minimize the post-thaw to insemination interval necessary to remove cryoprotectant while maintaining optimal sperm viability. In this study, man-

ipulations required to transfer and dialyze the microliter volumes of frozen semen were carried out with only a small reduction in motility. Maintenance of post-thaw motility was slightly, but significantly improved with glycerol removal. The relevance of greater velocity in these samples is not readily apparent. However, differences observed in motility of sperm after glycerol removal may translate into enhanced sperm survival in the more favorable environment of the female reproductive tract.

The results of this study are based on a limited number of observations, leaving many questions regarding cryopreservation of falcon semen unanswered. However, several important points can be drawn from these results. Peregrine semen can be frozen using glycerol as a cryoprotectant with good post-thaw sperm motility, and the glycerol can be rapidly removed from post-thaw semen by dialysis without substantial loss of sperm motility. The techniques used in these procedures are simple, relatively inexpensive, and can be adapted for practical application. Finally, the development of 2 kestrel eggs in a clutch of 6 suggests that post-thaw dialysis is potentially useful for successful breeding with frozen falcon semen. Use of homologous species for insemination may provide a more useful measure of fertility. Refinement of these procedures and use of additional females to test fertility will help to establish whether post-thaw glycerol removal will make the use of frozen semen a practical approach to captive breeding of falcons and other birds of prey.

#### ACKNOWLEDGMENTS

This project was supported in part by The Peregrine Fund, Inc., and the American Wildlife Research Foundation, Inc.

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Received 25 March 1985; Accepted 15 July 1985



# CHARACTERISTICS OF CLIFFS AND NEST SITES USED BY BREEDING PRAIRIE FALCONS

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**ABSTRACT** - Data from over 400 Prairie Falcon (*Falco mexicanus*) eyries in 8 states show a consistent pattern of eyrie placement relative to height and aspect of nest cliffs. Mean eyrie height averaged 63% of mean cliff height. Mean exposure of eyries and nest cliffs tended to be southerly with no significant difference between eyrie and cliff exposures. Potholes were the most frequently used nest sites. Patterns of occupancy and nest success in Wyoming were statistically independent of physical habitat variables measured. However, eyries on tall exposed buttes consistently had high failure rates that appeared weather related. Attributes of Wyoming eyries are presented and suggestions made for creating new eyries for Prairie Falcons as a management tool.

We summarized and compared data on nest cliffs and eyries used by the Prairie Falcon (*Falco mexicanus*) in the western United States. Included are data available in the literature and original data from eyries active between 1982 and 1984 in Wyoming. Our objective was to document the variation in nest cliffs and eyries used by these falcons and to identify consistent patterns of use. In our study, we examined the association between physical nesting habitat and patterns of eyrie occupancy and nest success. We discuss attributes of Prairie Falcon nest cliffs and eyries, and suggest guidelines for creating new falcon eyries.

## STUDY AREA AND METHODS

Data from 8 states were considered: Washington (Decker 1931), Wyoming-Colorado (Enderson 1964), Montana (Leedy 1972), Utah (Porter and White 1973), New Mexico (Platt 1974), Oregon (Denton 1975), Idaho (Ogden 1973; Ogden and Horkner 1977), and Colorado (Williams 1981).

We collected data from eyries and associated cliffs in southern Wyoming known to have been active between 1982 and 1984. We define *eyrie* as the area in and immediately around the nest scrape. *Nest cliff* was the rock formation above and below the eyrie. A single nesting territory may contain several separate nest cliffs and eyries that are occupied and defended in different years. We climbed to eyries by ladder or rope; nest cliff measurements were taken from below.

Variables measured at eyries centered on the nest scrape, if recognizable, or on the approximate center of the eyrie. These included roof (or overhang) height, width, length, and percent coverage of nest scrape by roof or overhang. We measured area of both entrance and floor with a transparent 25 cm<sup>2</sup> grid. Slope of both floor and ceiling were measured with a clinometer. Eyrie exposure was measured by placing a compass in the nest scrape and taking readings along a horizontal plane to both outside edges. From these azimuths (corrected for declination) we calculated mean and extent of horizontal exposure. Finally, eyries were classed as either potholes, horizontal ledges or shelves, vertical cracks or crevices, and stick nests.

Nest cliff measurements focused on that portion of the cliff directly above and below the eyrie. Variables included cliff and eyrie height, inclination of the toe slope below cliff (determined by clinometer), and aspect perpendicular to the cliff. Verticality of

each cliff was estimated with a large protractor and was either vertical (85-95°), overhung (<80°) or underhung (>100°). Cliffs were classed as: canyon walls, buttes or mountains, rimrock or ridges, and isolated rock outcrops.

Standard statistics are presented for most variables. Statistics from other studies, if not reported, were calculated from frequency tables or raw data. We analyzed our data using one-way ANOVA and Chi-square ( $\chi^2$ ) to examine relationships between physical variables and histories of nest success and occupancy within and among years. In among-year analyses, we only included sites with complete 3-yr histories.

Data suitable for circular statistical analysis (Batschelet 1981; Zar 1984) were available for Montana, Utah, New Mexico, Idaho, Colorado and Wyoming. Grouped data were analyzed as suggested by Batschelet (1981); 95% confidence intervals were estimated by interpolation (Batschelet (1981: Fig. 5.2 1). We used Rayleigh's test to determine statistical significance of mean exposures to infer nonrandom orientations (Zar 1984). Concentration ( $r$ ), or length of the mean vector as calculated by circular methods, ranges from 0 to 1 and is affected by variation in circular data, sample size, and grouping. Values of  $r$  near 1 indicate data points closely concentrated about the mean angle.

## RESULTS

**Eyries.** — Dimensions of eyries from the present study were summarized (Table 1), and comparable to Williams (1981) and Porter and White (1973). Williams (1981) reported eyrie lengths and widths which averaged 78.9 cm (SE = 7.63) and 81.1 cm (SE = 9.52), respectively. Both means were significantly less than measurements from Wyoming (t-Test;  $P < 0.01$ ). Roof heights of Colorado eyries (Williams 1981) averaged 83.2 cm (SE = 12.04), and were significantly greater (t-Test;  $P < 0.01$ ) than we found. The Colorado data yielded an average floor area of 6821 cm<sup>2</sup> (SE = 1198.22). Area within 8 eyries averaged 15,000 cm<sup>2</sup> in Utah (Porter and White 1973). Our estimate of area lies between these, but statistical comparisons could not be made.

Floors of most (80%) Wyoming eyries sloped downwards towards the front at 5-10°. Conversely, most (84%) eyrie roofs or overhangs sloped to the

Table 1. Attributes of Prairie Falcon eyries in southern Wyoming, 1982 to 1984.

VARIABLE	MEAN	SE	RANGE	N
Height (cm)	47.9	3.62	11-193	68
Width (cm)	91.2	7.45	18.313	70
Length (cm)	135.4	8.82	43-400+	71
Floor (cm <sup>2</sup> )	9325	769.83	1600-29275	70
Entrance (cm <sup>2</sup> )	5375	975.12	875-53500	56
Floor Slope (°)	7.4	0.78	-10-35	67
Roof Slope (°)	-12.3	2.23	-65-45	56

rear at a wide range of angles (Table 1). All eyries we examined, except for 2 (3%), had overhanging rock or ceilings protecting the nest scrape. Percent coverage of nest scrapes was frequently 100%, and averaged 93%.

Across their range, Prairie Falcons nested most frequently in potholes or on cliff ledges. Crevices and stick nests were used less frequently (Table 2).

**Nest cliffs.** — Heights of eyries and nest cliffs varied widely. Relative to mean cliff heights, mean eyrie heights varied from 60-70% (Table 3). Mean heights of eyries from 8 studies were highly correlated with mean heights of cliffs ( $R^2 = 0.99$ ;  $P < 0.001$ ), and averaged 63% of mean cliff height. Minimum cliff and eyrie heights reported in these studies were 2.1 m and 0.8 m, respectively. Signifi-

Table 2. Types of eyries used by nesting prairie falcons.

STATE	POTHOLE <sup>1</sup>		CREVICE <sup>2</sup>		LEDGE <sup>3</sup>		STICKNEST		REFERENCE
	n	(%)	n	(%)	n	(%)	n	(%)	
WY	29	(41)	17	(24)	18	(25)	7	(10)	This study
CO	2	(14)	9	(64)	3	(21)	--	--	Williams (1981) <sup>4</sup>
ID	76	(60)			24	(19)	26	(21)	Ogden and Hornocker (1977)
OR	15	(42)	14	(39)	7	(19)	--	--	Denton (1975) <sup>4</sup>
NM	8	(39)			4	(19)	9	(43)	Platt (1974)
UT	26	(36)	7	(10)	23	(32)	(16)	22	Porter and White (1973)
MT	18	(37)	18	(37)	9	(18)	4	( 8)	Leedy (1972)
CO-WY	20	(56)			16	(44)			Enderson (1964)
WA	6	(43)			1	(7)	7	(50)	Decker (1931)
	200	(45)	65	(15)	105	(24)	69	(16)	

<sup>1</sup>Includes sites listed as caves, holes and cavities.  
<sup>2</sup>Includes sites listed as vertical cracks.  
<sup>3</sup>Includes sites listed as horizontal shelves. Includes a few sites with sticknests present.  
<sup>4</sup>Data not reported but sticknests used.

Table 3. Mean heights of Prairie Falcon eyries and nest cliffs.

CLIFF HEIGHT (m)			EYRIE HEIGHT (m)			PERCENT <sup>1</sup> HEIGHT	REFERENCE
MEAN	(n)	RANGE	MEAN	(n)	RANGE		
14.6	(71)	4.3 - 34.6	9.8	(71)	2.9 - 30.6	67	This study
53.7	(14)	15 - 140	32.1	(14)	10 - 90	60	Williams (1981)
36.9	(49)	3.7 - 122+	22.9	(41)	2.1 - 61+	62	Denton (1975) <sup>2</sup>
14.0	(21)	6 - 35	8.6	(21)	3 - 30	61	Platt (1974)
30.4	(126)	2.3 - 122+	19.8	(126)	2.4 - 122+	65	Ogden (1973) <sup>2</sup>
31.0	(44)	2.1 - 154.4	19.6	(51)	0.8 - 137.2	63	Porter and White (1973)
38.1	(57)	9.2 - 92+	24.4	(57)	3.1 - 76.2	64	Leedy (1972) <sup>3</sup>
15.8	(36)	7.7 - 38.7	11.1	(36)	-- --	70	Enderson (1964)
29.3	(418)	2.1 - 154.4	18.5	(417)	0.8 - 137.2	63	Grand Mean

$$^1\text{Percent height} = \frac{\text{Mean eyrie height}}{\text{Mean cliff height}} \times 100\%$$

<sup>2</sup>Values biased low as some very tall eyries and cliffs were excluded.

<sup>3</sup>Approximate values.

cantly more Wyoming eyries were in the upper one-half of the cliffs than in the lower one-half ( $\chi^2$ ;  $P < 0.005$ ). But the upper and middle one-third of cliffs were used equally.

Inclination of toe slopes ranged from 0-36°. Most (57%) cliffs were vertical (85-95°), though many (34%) sloped back into the hill (> 100°). Only 9% were overhung (< 80°).

We found nest cliffs fairly evenly distributed among volcanic buttes or mountains (34%), sandstone canyons (30%) and isolated rock outcrops (25%). Few occurred on low rimrock (11%). In Oregon, Denton (1975) reported eyries on bluffs (38%), ridges (29%), canyons (24%) and outcrops (9%).

**Exposure of eyries and cliffs.** — Exposure data from 6 of the 8 western states are shown in Figure 1 (Appendix). Except for Utah and New Mexico, aspects of both cliffs and eyries was reported. In no case did the distributions of eyrie and cliff aspects differ significantly ( $\chi^2$ ;  $P > 10$ ). When 95% confi-

dence intervals could be calculated, intervals for eyrie exposure and cliff aspect overlapped extensively (Appendix; Fig. 3). Overall, mean eyrie aspects averaged 161.2° ( $r = 0.24$ ); mean cliff aspects averaged 158.3° ( $r = 0.19$ ). Due to large disparities in sample sizes, these grand means are biased toward our data from Wyoming.

Aspects of cliffs and eyries in Wyoming ranged from 0 - 360° (Fig. 2). We lumped eyrie exposures into 2 groups (northeast and southwest facing) and found that 70.2% faced southwest; close to the percentage (69.4%) of eyries that faced southwest in Utah (Porter and White 1973; Fig. 16). Extent of horizontal exposure of eyries we examined (Fig. 3) ranged from 5 - 160°, and averaged  $54 \pm 12^\circ$  ( $r = 0.83$ ). Williams (1981) reported "angles of view" ranging from 30 - 170° and averaging  $122 \pm 3^\circ$  ( $r = 0.74$ ).

Neither ANOVA nor  $\chi^2$  tests revealed any significant ( $P > 0.05$ ) relationships among physical traits, including exposures, of Wyoming eyries and histories of nest occupancy and success. This held true both within and among years.

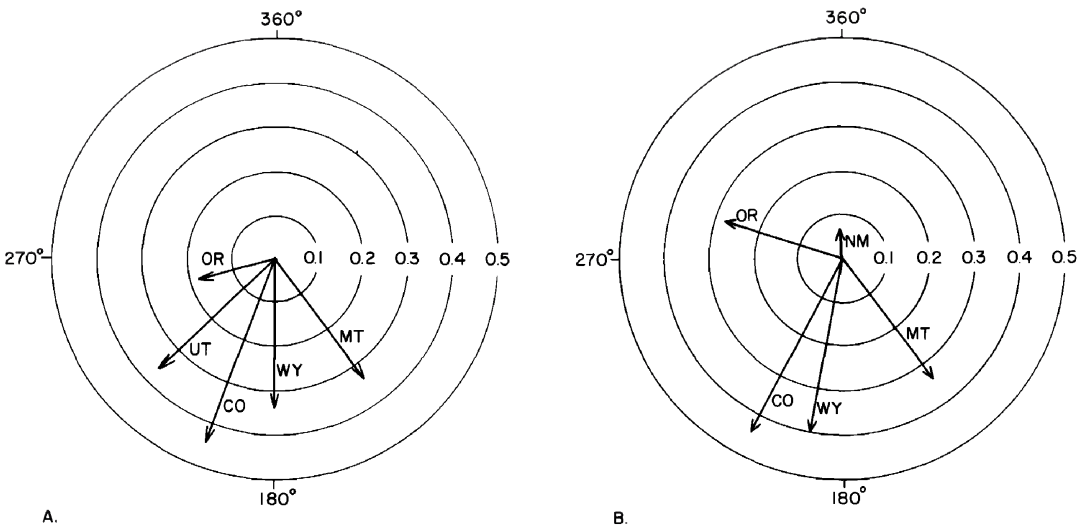


Figure 1. Mean aspect of Prairie Falcon eyries (A) or nest cliffs (B) in Montana, Colorado, Wyoming, Utah, Oregon and New Mexico. Vector lengths are proportional to degree of concentration (r) about mean aspect (Appendix).

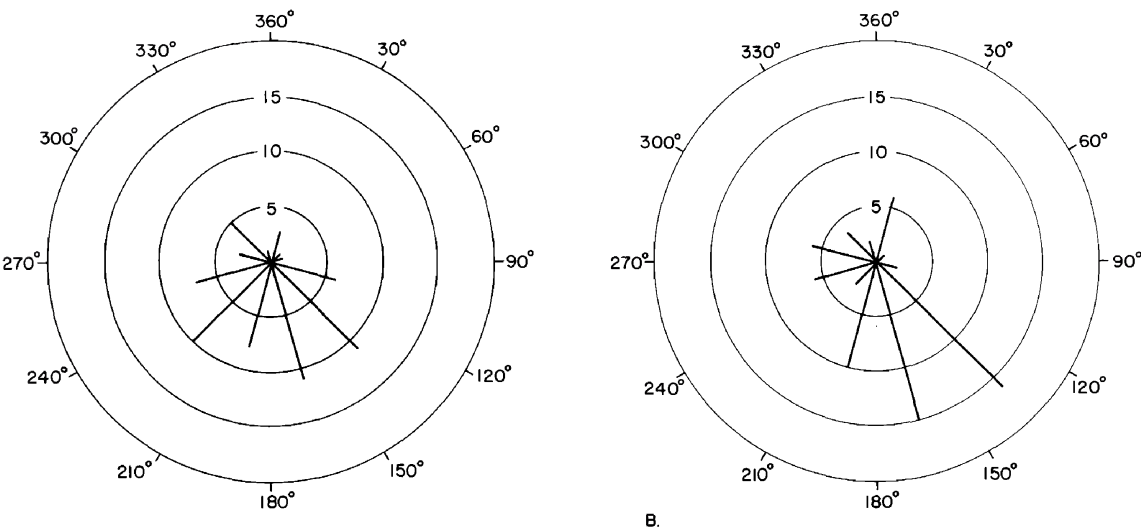


Figure 2. Frequency histograms of eyrie exposure (A) and cliff aspect (B) for Prairie Falcons in southern Wyoming, 1982-1984.

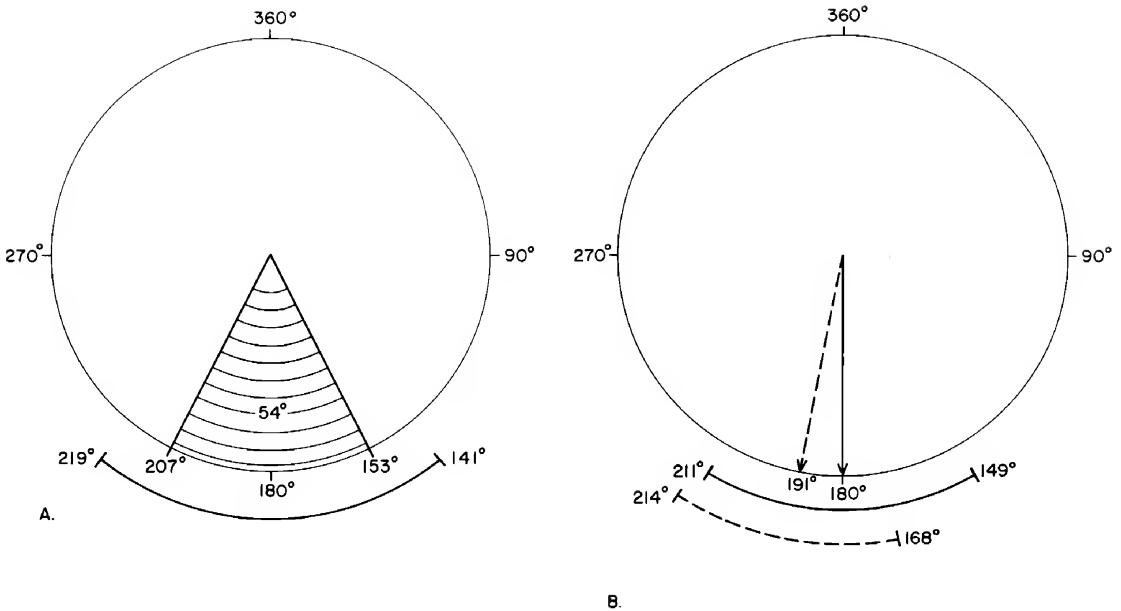


Figure 3. Means and 95% confidence intervals for (A) extent of exposure and (B) cliff aspect (broken line) and eyrie exposure (solid line), for Prairie Falcons in southern Wyoming, 1982-1984.

## DISCUSSION

Compared to other western raptors, Prairie Falcons have narrow nest site requirements. They nest almost exclusively on rock cliffs (cf., MacLaren et al. 1984). Nest cliffs used vary widely in height, location and aspect. Yet in the studies examined, Prairie Falcons demonstrated some consistent patterns in their use of eyries. Mean eyrie and cliff heights were strongly correlated and distributions of eyrie and cliff aspects were similar. We do not infer habitat selectivity because data on availability of potential eyries and nest cliffs have neither been collected by us nor presented in the studies we cite.

**Eyries.** — Potholes, reported most frequently, provide excellent shelter from both inclement weather and direct sunlight, but are not always available. In our experience, potholes occur most frequently in sandstone, while ledges and vertical cracks are more common in granite, basalt and conglomerate cliffs. Vertical cracks and crevices also provide excellent shelter and shade, but may be subjected to chilling drafts. Nests in crevices were reported infrequently in the literature but were common in our study area.

**Nest cliffs.** — Mean eyrie heights, as percentage of mean cliff heights, were surprisingly consistent and indicate extensive use of nest sites 60 - 70% up cliff faces. Further study is needed to explain this narrow range of eyrie heights relative to cliff heights. By nesting in the upper reaches of vertical cliffs, Prairie Falcons should be safe from mammalian predators. Such a location also provides a commanding view of the territory and of potential prey or predators. Depending on aspect and prevailing winds, updrafts along cliffs may aid the falcons when leaving the nest to hunt or defend territory. Convective updrafts may form more frequently on south-facing cliffs as they radiate more heat than cliffs with other aspects.

**Exposure.** — Prairie Falcons have long been known to nest on cliffs with southerly aspects (e.g., Dawson 1913). Sixty-one and 42% of the eyries studied by Enderson (1964) and Ogden (1973) faced south. But their data, as reported, could not be included in our circular statistics analyses. With 2 exceptions (Platt 1974; Denton 1975), the studies examined indicated southerly mean aspects (Fig. 1). Although cliff and eyrie exposure varied widely in



most studies, Rayleigh's test indicated significant nonrandomness in most cases (Appendix). Mean exposures were often only weakly significant ( $P < 0.10$ ) due to wide ranges of exposures and because most data from the literature were grouped into broad exposure classes. Aspects of nest cliffs in New Mexico and eyries in Oregon were random (Rayleigh's test;  $P > 0.10$ ). Excluding these, mean cliff aspect ranged from  $144 - 288^\circ$ , and mean aspect of eyries ranged from  $143 - 226^\circ$ . Prairie Falcons do use north-facing cliffs and eyries (Figs. 1 and 2). In fact, Tyler (1923) reported that most Prairie Falcon eyries in southern California had northerly aspects and none were southerly. He attributed this to a scarcity of south-facing cliffs and an abundance of north-facing cliffs. Our results demonstrate a tendency for Prairie Falcons to use southerly aspects, but do not demonstrate any benefit in terms of nest success. Eyrie configuration and location on the cliff may override efforts of cliff aspect (Ellis 1982). Data on availability of potential cliffs and eyries with differing aspects are needed to conclude that falcons actively select south-facing cliffs.

The microclimate within an eyrie is affected by its exposure and cliff aspect; southerly exposures likely help to moderate cold temperatures during incubation and brooding. Solar heating of nest scrapes may lessen the energy requirements of incubating and brooding falcons. The majority (97%) of eyries we examined had overhead protection. Most eyries examined by Enderson (1964), Leedy (1972), Platt (1974), Ogden and Hornocker (1977) and Williams (1981) were similarly sheltered. Overhead shade may be important during midday since nestlings exposed to direct sun when temperatures are near  $32^\circ\text{C}$  may die (Nelson 1969). Such temperatures are unusual during the nestling period in our study area, but use of shaded eyries may increase nestling survival at lower elevations and latitudes.

We believe shelter from late spring storms to be more important than protection from heat stress in our Wyoming study area. Such storms were associated with a high rate (64%) of nesting failure on buttes in 1983. A spring snowstorm this same year was followed by desertion of all 5 active nests on buttes in a small area of northeastern Wyoming (J. Squires pers. comm.). In our study area, territories on tall exposed buttes consistently suffered higher rates of nest failure (43 - 64%) than those located on

lower sheltered canyons, rims and outcrops (18 - 38%). However,  $\chi^2$  tests failed to confirm a significant association ( $P > 0.10$ ) between nest success and cliff location.

In our study, neither cliff nor eyrie aspect appeared to determine patterns of eyrie occupancy or nest success (see also Ogden and Hornocker 1977). Eyrie, but not cliff, aspect apparently affected nest success in Colorado (Williams 1981) where all 5 southwest-facing eyries failed in 1980. Williams attributed this to local weather patterns.

Biotic factors likely play a larger role than physical habitat in determining occupancy and nest success in Prairie Falcons. Though not confirmed by statistical analyses ( $\chi^2$ ;  $P > 0.10$ ), nesting Great-horned Owls (*Bubo virginianus*) were often associated with unoccupied and unsuccessful falcon territories in our study area. Although we did not quantify accessibility of eyries to mammalian predators, this may be an important factor (Ogden and Hornocker 1977). Abundance of prey clearly affects Prairie Falcon productivity and nest success. Townsend's Ground Squirrel (*Spermophilus townsendi*) densities in Idaho accounted for over 98% of the annual variation in Prairie Falcon productivity (USDI-BLM 1979).

**Management implications.** — Mitigation for loss of suitable nesting cliffs due to energy, urban, or recreational development may be needed in some areas. An obvious solution is the creation of new nest sites. Such sites were rapidly colonized in California (Boyce et al. 1980) and Alberta (Fyfe and Armbruster 1977). Because the size of the non-breeding population of Prairie Falcons may be as high as 25% of the breeding population (Runde in prep.) substantial population increases seem possible, but will depend upon the local availability of prey and foraging habitat.

The data presented here suggest locating new nest sites on south-facing cliffs about two-thirds up the cliff. Area of the floor should be at least 7,000  $\text{cm}^2$ , and slope gently ( $5 - 10^\circ$ ) to the front. Overhead cover should be present, and horizontal exposure should be about  $54^\circ$  (Fig. 3A). If eyries are to be created on mine highwalls as part of habitat reclamation or mitigation, their legal, hydrological, and physical constraints must first be addressed (Tessman 1984). The data in Table 3 suggest that cliffs, or highwalls, selected for eyrie creation be at least 2.1 m tall.

We suggest that newly created eyries be clustered

together to mimic nesting territories with several alternate nest sites. These new territories could be spaced approximately 1-2 km apart unless visual barriers are present to separate them. In this situation, we have seen successful nests as close as 150 m. Our data show that in a 3-yr period over one-half of the eyries were only occupied 1 yr, and 23% were occupied 2 yrs. Similar findings were reported by Enderson (1964) and Ogden (1973). We suggest that 2 or 3 nest sites be provided per cliff. The ability to use alternate eyries within a nesting territory may help to reduce direct competition for nest sites with owls, and may decrease the frequency of parasitic infestations.

#### ACKNOWLEDGMENTS

Tricia MacLaren helped locate and collect data from the Wyoming eyries. Richard Guenzel programmed the circular statistics calculations. James Enderson, Grainger Hunt, Larry Irwin, James Mosher and Karen Steenhof reviewed earlier versions of this paper. This study was supported by the BLM, the Wyoming Cooperative Fish and Wildlife Research Unit, USFWS, National Wildlife Federation, and the late Robert Runde.

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Received 1 May 1985; Accepted 20 September 1985

Appendix: Mean aspect of Prairie Falcon eyries and Prairie Falcon nest cliffs.

STATE	MEAN ASPECT <sup>1</sup>	r VALUE	SIGNIFICANCE LEVEL <sup>2</sup>	N	REFERENCE
<b>Eyries</b>					
Wyoming	180°±31°	0.41	P<0.001	67	Present study
Colorado	200°±60°	0.44	P<0.10	14	Williams (1981)
Oregon	255°	0.18	P>0.10	36	Denton (1975)
Utah	226°±34°	0.36	P<0.01	49	Porter and White (1973)
Montana	143°±33°	0.34	P<0.001	49	Leedy (1972)
<b>Cliffs</b>					
Wyoming	191±23°	0.40	P<0.001	71	Present study
Colorado	200°±60°	0.44	P<0.10	15	Williams (1981)
Oregon	288°±51°	0.28	P<0.10	36	Denton (1975)
New Mexico	353°	0.07	P>0.10	21	Platt (1974)
Montana	144°±35°	0.34	P<0.01	45	Leedy (1972)

<sup>1</sup>With 95% confidence interval, when calculable.

<sup>2</sup>Rayleigh's test.

# DEVELOPMENT OF HUNTING AND SELF-SUFFICIENCY IN JUVENILE RED-TAILED HAWKS (*Buteo jamaicensis*)

SARA JANE JOHNSON

**ABSTRACT** - Forty-eight juvenile Red-tailed Hawks (*Buteo jamaicensis*) were observed for 2 mo following fledging. Their flight activity and capture rate of vertebrate prey were quantified as a means of describing development of self-sufficiency. As juveniles aged, increasing amounts of time were spent in hunting versus nonhunting activities, and versatility of hunting methods increased. Capture of vertebrate prey began 42 d after fledging, but parents continued to provide food at least to 53 d past fledging. Development of self-sufficiency was indicated to be a gradual process whereby juveniles progressively capture more and more of their own food while parental food provision declines.

During 2 yrs of field study on post-fledging behavior of the Red-tailed Hawk (*Buteo jamaicensis*) (Johnson 1973), I rarely saw juveniles capture vertebrate prey. This limited hunting ability of juveniles during the early post-fledging period was consistent with both Amadon's (1964) and Ashmole and Tovar's (1968) assumptions that the long post-fledging period in many species of birds is an adaptation to enhance survival of juveniles while they acquire specialized feeding techniques. Juvenile foraging behavior in a variety of bird species has been quantified to indicate progressive improvements in foraging efficiency through increases in hunting versus nonhunting activities (Buckley and Buckley 1974; Davis 1975), as well as progressive development of increasingly complex capture techniques (Dunn 1972; Smith 1973; Buckley and Buckley 1974; Feare 1975; Davies 1976; Davies and Green 1976). For raptors, development of juvenile hunting skills in the field has been defined in descriptive rather than quantitative terms, and only for several species such as the Swainson's Hawk (*Buteo swainsoni*) (Fitzner 1979) and Peregrine Falcon (*Falco peregrinus*) (Sherrod 1983). The objective of this study was to describe the development of self-sufficiency of the juvenile Red-tailed Hawk in the early post-fledging period by quantifying flight types when juveniles remained localized in the vicinity of the parental territory.

## METHODS

I conducted my study during the 1971-1973 breeding seasons in the Gallatin Valley, Gallatin Co., Montana. For details of the site see Johnson (1973). The Gallatin Valley is comprised of a mixture of pasture and dryland farming. Deciduous trees generally occur only along rivers and creeks.

A total of 48 juveniles were observed, 21 from 8 nests in 1971, 20 from 8 nests in 1972, and 7 from 2 nests in 1973. All juveniles were color-marked on ventral wing surfaces with nontoxic enamel spray paint. No abnormal wear and tear was observed on marked feathers. Radio transmitters were placed on 10 and 6 juveniles in

1972 and 1973, respectively. Transmitters weighed up to 41 g, including the harness, frequency range 150-151 mhz, and transmitted approximately 0.3 km at ground level to 25-31 km from the air. Transmitters were monitored with a 12-channel AVM portable receiver and four-element Yagi antenna. A double-layered polyethylene harness held the transmitter on the bird's back between the wings with the antenna extending parallel to the tail. A dissolvable gut suture attachment gradually deteriorated and allowed the harness to eventually fall off the bird. The earliest any harness fell off was 33 d following placement on the bird. The influence of the transmitter on the hawk's flight behavior was unknown; some influence may have been possible.

Frequency, but not duration, of 7 flight types was measured during hour-long observation periods throughout each day between 0900 H and 1900 H. Measurements were initiated on an opportunistic basis when located birds became active. Due to difficulty in locating untagged birds, most flight measurements were recorded on radio-tagged individuals. The 7 flight types quantified included 1) perch/perch-direct flights between 2 elevated perches, 2) perch/quarter-indirect flights between elevated perches during which birds engaged in random quartering flights within 3-15 m of the ground, 3) perch/ground-direct flights from an elevated perch to the ground, 4) quarter/ground-indirect flights to the ground during quartering flights, 5) ground/ground-flights which were initiated and terminated on the ground, 6) perch/adult-approaches to the parent birds and 7) perch/soar-initiation of soaring flights.

I considered 3 of the above flights as hunting activity: perch/quarter, quarter/ground and perch/ground. Quartering flight is a common prey-search method for buteos (Wakeley 1974), and Red-tailed Hawk flights to the ground generally occur during prey-capture attempts. In some instances, the 3 flight types I have identified as hunting activity may not have actually involved hunting activity. However, there is no means of separating these out, and I do not believe they contribute any significant problem to data collection.

The 4 remaining flight types were defined as general movement activity (perch/perch, perch/soar), harassment of parent birds for food (perch/adult) and play and/or capture of invertebrates (ground/ground). I did not consider soaring flight a juvenile hunting activity; during the 3 field seasons, I never observed soaring juveniles attempting to capture ground-level prey. I did observe soaring juveniles grab air-borne invertebrates with their feet.

For purposes of analysis, I combined the hourly observation samples into 5 age classes. Age classes were initially designated at 10-day intervals, since notable range expansions of juveniles occurred at approximately 20 and 30 d past fledging (Johnson 1973). However, because the number of monitored individuals

Table 1. Mean ( $\pm$  S.D.) number of moves per hour by age class for 7 types of flights by juvenile Red-tailed Hawks. The sample is based on a total of 48 known-aged juveniles observed during 3 breeding seasons. Percentages (in parentheses) include only the non-soaring flight activities.

AGE PAST FLEDGING (DAYS)	HOURS OBSERVED	PERCH/ PERCH	PERCH/ QUARTER <sup>1</sup>	PERCH/ GROUND	QUARTER/ GROUND	GROUND/ GROUND	PERCH/ ADULT	PERCH/ SOAR	TOTAL MOVES
0-10	22	2.14 $\pm$ 1.46 (92.2)	---	0.18 $\pm$ 0.39 (7.9)	---	---	---	---	2.32 $\pm$ 1.45 ---
11-20	62	3.21 $\pm$ 2.93 (75.0)	0.19 $\pm$ 0.43 (4.4)	0.79 $\pm$ 1.06 (18.5)	0.06 $\pm$ 0.25 (1.4)	0.03 $\pm$ 0.00 (0.7)	---	0.10 $\pm$ 0.35 ---	4.38 $\pm$ 3.26 ---
21-30	117	2.03 $\pm$ 1.73 (55.0)	0.32 $\pm$ 0.80 (8.7)	1.09 $\pm$ 1.34 (29.5)	0.02 $\pm$ 0.13 (0.5)	0.16 $\pm$ 0.62 (4.4)	0.07 $\pm$ 0.41 (1.9)	0.34 $\pm$ 0.61 ---	4.03 $\pm$ 2.63 ---
31-43	55	2.75 $\pm$ 2.23 (47.8)	0.58 $\pm$ 1.01 (10.1)	1.91 $\pm$ 1.76 (33.2)	0.09 $\pm$ 0.45 (1.6)	0.27 $\pm$ 0.80 (4.7)	0.15 $\pm$ 0.36 (2.6)	0.43 $\pm$ 0.62 ---	6.18 $\pm$ 3.40 ---
44-57	58	1.90 $\pm$ 2.16 (39.4)	1.38 $\pm$ 1.93 (28.6)	0.97 $\pm$ 1.60 (20.1)	0.21 $\pm$ 0.55 (4.4)	0.07 $\pm$ 0.37 (1.5)	0.29 $\pm$ 0.79 (6.0)	0.38 $\pm$ 0.86 ---	5.20 $\pm$ 3.49 ---

<sup>1</sup> Quartering flights which resulted in prey-capture attempts are included in another category.



decreased as older fledglings died or dispersed, the older age classes were extended to increase sample size as follows: 1-10, 11-20, 21-31, 31-43 and 44-57 days after fledging.

During the hourly observation periods, I recorded all instances where juveniles captured vertebrate prey. I did not disturb the birds who had captured prey in order to identify the prey item. Due to the distances from which I observed the birds ( $\geq 300$  m to avoid influencing behavior) I was unable to identify any species of vertebrates captured. I was able to distinguish between a juvenile's capture of vertebrates versus invertebrates. Vertebrate prey was visible in the bird's talons, whereas invertebrate prey was not. When no prey was visible during juvenile bill-cleaning activity (which follows feeding), I assumed the bird had been consuming invertebrates.

## RESULTS

A summary of juvenile Red-tailed Hawk flights through the first 2 mo after fledging is given in Table 1. These data were analyzed using the Friedman Two-Way Analysis of Variance by Ranks (Siegel 1956). Distributions of the 7 juvenile flight types were significantly different ( $P \leq 0.01$ ) between the 5 age classes.

**First 3 Weeks After Fledging.** This period includes the 0-10 and 11-20 d age classes. The young Red-tailed Hawk activity level was lowest immediately after fledging, but essentially doubled within 3 wks as juvenile flight endurance improved. During this initial post-fledging period, the most common juvenile flight type was the simple, direct flight between elevated perches, which comprised 92% of all flights during the young's first 10 d out of the nest. Hunting-related activity was limited during this period. Even in the 11-21 age class, flights to the ground and aerial searching via quartering flight comprised only 24% of all hourly flights. However, not all flights to the ground during this period involved hunting. Birds also went to the ground to retrieve food, or simply because they were unable to sustain their flight.

As this initial fledging period progressed, juveniles moved more easily between elevated perches and the ground, so that their use of the ground increased. At the same time, juveniles spent greater amounts of time away from the nesting trees in open fields where fence posts were available for perching. Direct flights to the ground from elevated perches comprised most of the hunting-related activity, and by 3 wks after fledging comprised 76% of hunting activity. The most limited hunting activity was dropping to the ground from quartering flights. Although these comprised 24% of all quartering flights, I believe many resulted

from the juvenile's poor flight endurance.

No juveniles were observed pursuing or capturing vertebrates during this period. The adults appeared to provide all vertebrate food for their young. The former were observed bringing food to the nesting area at least 4-5 times/d. To an unknown extent, juveniles supplemented their diet with ground-associated invertebrates captured themselves.

Soaring flight behavior began developing at the end of this period. These flights were generally of only several min duration. Ground to ground flights, which were associated with play activity, involved both single individuals or groups of siblings. Play involved pursuit of, striking at and wing-beating inanimate objects and/or invertebrates. Sticks and dirt clods were carried around in the bird's beak or talons. Occasionally, birds pursued objects which they had tossed from their beak. Grounded play activity was usually interspersed with dusting and resting activity. During this period, juveniles remained grounded continuously at times up to 18 minutes.

**Four To Six Weeks After Fledging.** This period includes the 21-30 and 31-43 d age classes. Juvenile Red-tailed Hawk activity levels reached their peak within 6 wks after fledging. At this time, only 48% of the flights/h involved direct perch to perch movement, while 45% involved hunting activity. The dominant hunting activity was still prey-capture attempts directly from perches. These totaled 74% of all hunting-related flights/h and 95% of all prey-capture attempts. Prey-capture attempts occurred during 13% of the quartering flights.

During this period, juveniles were observed pursuing vertebrates. At 35 d after fledging, an individual pursued but didn't contact a Striped Skunk (*Mephitis mephitis*). At 38 d after fledging, a 2nd juvenile followed a flock of English Sparrow (*Passer domesticus*). At 41 d after fledging, a 3rd bird attempted to capture a Black-billed Magpie (*Pica pica*) in a heavy clump of tree branches. And at 41 d after fledging, a 4th bird dove repeatedly at a Red Fox (*Vulpes vulpes*).

It appeared that juveniles were still obtaining most, if not all of their vertebrate food from the parents during this period. Food transfers between parent and offspring were now initiated by the juveniles. Observations of adults carrying food to their young were rare and were only noted for juveniles fledged  $< 35$  d. Juvenile approaches to

parents increased continually through this period. Juveniles were observed approaching and taking food from parents 19 times. In 13 instances juveniles had been hunting with adults in hunting areas, and in 6 instances juveniles flew to adults from other areas of the territory. Adults readily gave up food to their young during this period.

Juveniles also obtained food from other non-sibling juveniles within a juvenile staging area located within the study area and from migrant adult Red-tailed Hawks who were moving through the area. Juveniles obtained food by taking it directly from other juveniles, and also by waiting for adults and possibly other juveniles to abandon food after feeding.

Soaring and ground play activity both increased through 6 wks after fledging. Juveniles spent continuous periods of 1 hr or more soaring. Soaring activity appeared to include exploration of the parental territory and surrounding areas, migration and social and play activity. Groups of up to 20 juveniles were observed soaring together. Play activity consisted of stoops where 2 birds made simultaneous vertical drops of 10-30 m or greater. During ground play, juveniles were observed grounded an hour or more at one time.

**Seven To Eight Weeks After Fledging.** This period includes the 44-57 d age class. During this last period, the number of juvenile ground-associated flights declined from previous age classes. The biggest decline occurred for general activity between perches; these fell to 40% of all hourly flights. In turn, hunting-related flights now comprised 53% of all hourly flights. Within hunting activity, there was a shift in the dominance from direct prey-capture attempts from perches to aerial searching activity via quartering flight. The latter comprised 62% of all hunting flights. The percentage of such flights which resulted in prey-capture attempts, however, remained at 13%. Thus the dominance of prey-capture attempts made directly from perches continued, although it declined to 82% of all attempts.

During this period, juveniles were observed capturing small vertebrates. In all cases, the suspected prey species were small rodents. Ages of birds involved were 44, 47, 52 and 53 days past fledging. Juveniles were still obtaining an unknown percentage of their food from the parents during this period, and offspring approaches to parents continued to increase in hourly frequency.

Juveniles were observed 10x to take prey from parents. Nine incidents occurred when juveniles were hunting close to adults, while 1 incident involved a longer approach across the parental territory. I observed parents resisting food piracy by their offspring during this period. Incidents involved parents carrying food away from, as well as taking food back away from, their offspring. Additionally, I saw 1 adult strike at (loosening feathers) and drive its young away several hundred meters. This attack appeared to stem from repeated harassment by the juvenile for food.

#### DISCUSSION

Development of self-sufficiency in juvenile Red-tailed Hawks is a gradual process. Flight activity and capture rate of vertebrate prey changed progressively through the first 2 mo after fledging. The shift with age in the juvenile's use of flight types resulted in a progressive increase in hunting versus non-hunting activity. At the same time, juvenile versatility of hunting methods increased. Initial hunting activity was comprised mostly of searching and prey-capture attempts from perches. Gradually their use of aerial searching via quartering flights increased, as did prey-capture attempts initiated from quartering flights. A similar increased use of quartering flights for searching out prey with increasing juvenile age has been reported for Swainson's Hawks (Fitzner 1979), and progressions in complexity of capture techniques have been noted in a variety of nonraptorial bird species (Dunn 1972; Smith 1973; Buckley and Buckley 1974; Feare 1975; Davies 1976; Davies and Green 1976).

Juveniles were first observed capturing vertebrate prey during week 7 after fledging. This likely reflects the average age that juveniles begin capturing vertebrates, since it is unlikely all young develop at the same rate. Development of hunting ability among young Peregrine Falcons has been found to vary considerably (Sherrod 1983).

Gradual development of hunting in young Red-tailed Hawks is similar to that described for young Peregrine Falcons (Sherrod 1983). Both cumulative experience and increasing versatility of capture techniques are likely involved with improved ability to capture vertebrates at young age. Experience, particularly in the form of encounters with live prey, has been shown to be important in the development of self-sufficiency of young rap-

tors; through such encounters, juveniles can learn to select capture opportunities which have a reasonable probability for success (Sparrowe 1972), as well as to select appropriate prey size (Mueller and Berger 1970). Lack of experience was likely involved in the juvenile Red-tailed Hawk's approach to inappropriate prey species such as the Red Fox and Striped Skunk, and initiation of such futile capture attempts as pursuing aerial flocks of passerines and Black-billed Magpies through heavy cover. Similar approaches of inappropriate prey by young Peregrine Falcons has also been observed (Sherrod 1983). The importance of experience seems to be born out by the very low capture rate of vertebrate prey I observed for juvenile Red-tailed Hawks (5 captures during 313 h of observation). Similarly, Sherrod (1983) observed that young Peregrine Falcons make hundreds of pursuits on prey before they begin making kills.

Increasing versatility of capture techniques, where young Red-tailed Hawks used more and more aerial searching for prey, may improve prey capture opportunities. Aerial versus stationery searching has been found to result in more successful hunting for the Ferruginous Hawk (*Buteo regalis*) (Wakeley 1974) and Black-shouldered Kite (*Elanus caeruleus*) (Tarboton 1978).

It was not possible from the study to determine at exactly what age juvenile Red-tailed Hawks become self-sufficient. However, it appears that even at 7 wks past fledging, when young begin to capture vertebrate prey, they remain dependent upon adults for a part of their diet for a continued period of time. Young Red-tailed Hawks were observed obtaining food from parents up to 53 d after fledging and possibly did so for a longer period. Juveniles were observed associating with parents as long as 70 d after fledging (Johnson 1973). Juvenile approaches to parents also continued to increase through 8 wks after fledging. As has been indicated for young Peregrine Falcons (Sherrod 1983), juvenile Red-tailed Hawks may not be initially able to capture vertebrate prey on a consistent basis, and thus remain dependent upon parental support through this transition period to independent feeding. This would allow them to continue to build up fat reserves for their first fall of independence. Both Peregrine Falcons (Sherrod 1983) and Swainson's Hawks (Fitzner 1979) continue to feed their young for some time after the latter begin capturing vertebrates.

The social behavior of both juvenile and adult Red-tailed Hawks seems well suited for the progressive post-fledging development of independence in juveniles. Juveniles were attracted to suitable hunting areas within the parental territory through associations with parents and to hunting areas outside the parental territory through associations with non-sibling juveniles. A similar example of local enhancement, or use of conspecifics to key in on profitable hunting areas, has been noted in other raptor species such as harriers during migration when birds are unfamiliar with local distributions of prey (Ward and Zahavi 1973), by vultures in the Serengeti where carcasses are widely distributed at times (Sinclair and Norton-Griffiths 1979), and by Bald Eagles (*Haliaeetus leucocephalus*) when they are concentrated in wintering areas (Knight and Knight 1983). Juvenile Red-tailed Hawks may also benefit from social behavior in staging areas by obtaining food from other more highly skilled juveniles. Outside of staging areas, social behavior will benefit juveniles by decreasing the effectiveness of adult Red-tailed Hawk territorial defense. The latter have difficulty driving off large numbers of intruders.

The social behavior of juvenile Red-tailed Hawks, along with their ability to capture ground-associated invertebrates, may explain why many individuals disperse from the parental territory as early as a month after fledging (Johnson 1973) even though they do not begin capturing vertebrate prey until around 7 weeks after fledging on the average. Juveniles are probably able to survive by feeding on invertebrates and pirating food from other juveniles until they themselves acquire sufficient hunting skills. I have no evidence to indicate that early dispersing juveniles have either a lower or higher survival rate than later-dispersing individuals. However, since the variable dispersal age pattern of juveniles continues to be expressed in the Red-tailed Hawk population, it would seem to have some adaptive value. If so, I would suggest that this variable dispersal pattern may benefit the overall reproductive success of the population by extending the feeding opportunities of newly-fledging offspring over a larger area rather than restricting all siblings to the parental territory.

#### ACKNOWLEDGMENTS

I am indebted to Byron E. Harrell and Robert E. Moore for advice in developing the study, to Thomas H. Glorvigen for field assistance, to R.E. Moore and Mary M. Meagher for critical review

of the manuscript, and to David Struckman-Johnson for assistance in statistical analysis of the data. I am also appreciative to William G. Cochran for providing telemetry equipment. Support for this study was provided by the Frank M. Chapman Memorial Fund of the American Museum of Natural History, the Society of Sigma Xi, the Foundation for Environmental Education and Montana State University.

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Received 22 February, 1985; Accepted 13 January 1986



# POST FLEDGING BEHAVIOR OF FERRUGINOUS HAWKS IN NORTH DAKOTA

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**ABSTRACT** - Post-fledging activities of 18 Ferruginous Hawks (*Buteo regalis*) were studied in southcentral North Dakota during July and August 1979. The post-fledging period ranged from 10 to 40 d ( $\bar{x}$  = 23.1 d; N = 16). Haylands and native prairie grasslands were the principal land use types utilized by fledglings and adults. Mortality of young during post-fledging was 11% (N = 2).

Brown and Amadon (1968) concluded that mortality rates were high for young hawks during the post-fledging period. However, increased mobility of fledglings creates problems in collecting information on their daily activities during this period. Consequently, little information is available about post-fledging periods (the time between leaving the nest and leaving the home range) of young raptors. Angell (1969), Lokemoen and Duebbert (1976), Thurow, et al. (1980), Powers (1980), and Harmata (1981) described some aspects of post-fledging activities of the Ferruginous Hawk (*Buteo regalis*). In recent years the use of radio telemetry has provided an effective but expensive method of studying post-fledging behavior. Blair and Schitosky (1982) studied 6 fledgling Ferruginous Hawks using radio telemetry in South Dakota, and Ensign (1983) and Woffinden and Murphy (1983) each studied 2 fledgling Ferruginous Hawks with radio telemetry equipment in Montana and Utah, respectively.

We studied post-fledging activities of Ferruginous Hawks in an area of North Dakota with an abundant nesting population (Gilmer and Stewart 1983) and open, flat terrain that facilitated observations of color-marked hawks. The study objectives were (1) to determine lengths of post-fledging periods for Ferruginous Hawks, (2) to assess habitat use by fledglings and adults relative to land use types surrounding nest sites, and (3) to determine fledgling mortality rates during the post-fledging period.

## STUDY AREA AND METHODS

The study area was located about 80 km west of Jamestown, North Dakota, an area known to have a dense nesting population of Ferruginous Hawks (Gilmer and Stewart 1983). The land surface was shaped by Wisconsin-age glaciers and topography varied from flat or gently rolling glacial outwash plains to rugged hilly areas of terminal moraine in the geologic subregion known as the Missouri Coteau. Land use practices formed a mosaic of agricultural lands and native eastern mixed-grass prairie (see Stewart 1975) interspersed with numerous wetlands. Small grains,

sunflowers (*Helianthus annuus*), and domestic hay were the principal crops grown, and native prairie grasslands served as livestock pasture.

Behavior of fledgling Ferruginous Hawks was studied from 8 July to 22 August 1979 by observing 18 fledglings raised in 4 tree nests and 1 ground nest. Four young hawks fledged from 3 nests and 3 young fledged from 2 nests. All 18 fledgling Ferruginous Hawks were banded with numbered U.S. Fish and Wildlife Service lock-on bands, and fitted with colored tail streamers for individual identification.

Tail streamers were made with colored, 4 cm wide Scotch plastic tape folded around a 2 cm wide strip of reinforced strapping tape, forming a seam midway along the ventral side of the streamer. The tail streamers measured 12.5 cm in length and the corners were trimmed off. Tail streamers were attached to the dorsal side of a central (number 1) rectrice with a fast drying, permanent bond Super Glue applied to the area of feather attachment. Four paper staples were fastened across the feather shaft in 2 Xs to assure solid contact between feathers and streamers, and to provide reinforcement. Streamers extended 5 cm beyond the end of the tail feathers. Yellow, blue, red and green colored plastic tape was used for individual identification of siblings (additional colors are also available). The bright colors and reflecting properties of the plastic tape provided a high degree of visibility. Although the tail streamers were small, they were visible on perched or flying hawks from 40 m with unaided eyes and over 300 m with 8 x 30 binoculars. The most readily visible colors in order of decreasing visibility were yellow, blue, red and green. The tail streamers were very durable, showing no wear after 5 weeks. One tail streamer was lost after 21 d. No adverse effects on movements, flight or behavior were noted.

We tried to locate each fledgling and adult from each nest daily. Each nest site was visited approximately an equal number of times during each of 4 daylight periods, 0530-0930 H, 0930-1330 H, 1330-1730 H and 1730-2130 H. Fledglings usually perched near each other on elevated sites and therefore were usually readily observed from a nearby road with binoculars or a spotting scope. Occasionally it was necessary to search surrounding areas on foot with the aid of a dog to ensure any fledglings overlooked were not hiding or dead.

High altitude, color infrared photographs (scale 1:63,360) of southcentral North Dakota acquired by the National Aeronautics and Space Administration in June 1978 were used to construct land use maps of the area surrounding each nest. These maps were checked for accuracy during ground visits. Habitat within the area was classified according to land use (i.e., native prairie, haylands, cultivated fields, or other areas including wetlands, farmsteads and roads not used by the hawks). To determine habitat use by each hawk family, locations of each fledgling and adult hawk observed during daily nest visits were plotted on the land use maps. We considered the area within 0.9 km of each nest



to contain the habitat available for use by the family group because it included the most distant sightings of adults from all nests during the post-fledging period. The habitat available to the hawks within 0.9 km of the nest (2.5 km<sup>2</sup>) was then compared with habitat the hawks were observed to use within the 2.5 km<sup>2</sup> area.

## RESULTS AND DISCUSSION

**Post-fledging Period.**— Mean length of the post-fledging period was 23.2 d (N = 16; range 10 - 40 d) and differing by as much as 15 d among nestmates (Table 1). In South Dakota most Ferruginous Hawk family groups left nest sites soon after young fledged, but some remained in the vicinity of nests for more than 30 d (Lokemoen and Duehbert 1976). In Idaho Ferruginous Hawk family groups remained in the area surrounding the nest sites for 3 - 4 wk (Thurow et al. 1980). In Montana Ensign (1983) noted that family groups were commonly observed up to 3 wk after fledging, and 2 radio-tagged fledglings remained 4½ wk. in Utah 2 radio-tagged fledglings remained in the nesting area 20-30 d after fledging (Woffindin and Murphy 1983.)

We flushed fledglings to locate them when it was necessary and noted that their flight capabilities developed rapidly after leaving the nest. However, the fledglings were rarely observed flying until the third week after fledging when they were occasionally seen flying or soaring in the home range. Ensign (1983) noted flight was "mastered" in the second week. Increased flights were probably associated with the progressive development of the

quills of the remiges and retrices during the first 2 wk after fledging (Brown and Amadon 1968:102).

Movements of fledglings during the post-fledging period were influenced by land use practices, availability of perches, movements of adults and activities of farmers. Availability of specific habitats and associated perches appeared to determine most movements of fledglings. Perches used included fenceposts, haystacks, large round hay bales, trees and metal power line towers. Dissimilarly, Blair and Schitosky (1982) observed a consistent weekly expansion of the range of 6 radio-tagged fledglings in a homogeneous grassland. Ensign (1983) reported 2 radio-tagged fledglings traveled 1,000 m from the nest site during the second week after fledging and 1,600 m during the third and fourth weeks in a sagebrush-grassland ecotone.

Fledglings gradually became independent from adult home ranges and family units as their flight capabilities developed. All fledglings left their home ranges by 18 August. Ferruginous Hawk family groups broke up gradually. In each instance young separated from the family while adults continued to occupy home ranges after the fledglings reached independence. Fledglings may also leave the adult home range before adults in South Dakota (Blair and Schitosky 1982) and Utah (Woffindin and Murphy 1983). Newton (1979) reported there is little evidence that raptors migrate as family groups.

**Habitat.**— Hayfields and native prairie grasslands were the habitats used most within each home range by adults as well as fledglings (Table 2). These vegetation types provided prime hunting areas for rodents. At nests A, B, D and E hayland was used in greater proportion than its availability. In 2 instances hayfields adjacent to adult hunting fields were utilized the day of mowing and regularly thereafter, and the fledglings moved to these fields within 2 d. Becard (1980) noted a similar response for the Swainson's Hawk (*Buteo swainsoni*). Wakeley (1978a, b) reported that density of vegetation was a more critical factor in a Ferruginous Hawk's choice of hunting sites than prey density. Apparently prey are more visible in recently cut hayfields. Cultivated fields were only rarely used during the post-fledging period by Ferruginous Hawks, while wetlands, farmsteads and highways were not used during our observations.

**Mortality.**— Two of the 18 fledglings died during the post-fledging period. One fledgling was

Table 1. Duration (in days) of post-fledging period of Ferruginous Hawks in North Dakota, 1979.

NEST	FLEDGLING TAIL STREAMER COLOR			
	YELLOW	BLUE	RED	GREEN
A	27	28	(6) <sup>a</sup>	26
B	24	27	25	--
C	40	29	(10) <sup>b</sup>	29
D	17	19	32	--
E	10	12	13	12

<sup>a</sup> Fledgling shot

<sup>b</sup> Fledgling fatally injured

Table 2. Habitat use by fledgling Ferruginous Hawks relative to habitat available within 0.9 km radius of each nest in North Dakota.

NEST	NATIVE		CULTIVATED	
	PRAIRIE	HAYFIELD	FIELDS	OTHER <sup>1</sup>
A	58 <sup>2</sup> -25 <sup>3</sup>	27-70	11-5	4-0
B	8-0	39-88	52-12	11-0
C	85-100	0-0	15-0	0-0
D	19-0	27-100	39-0	15-0
E	19-3	31-97	23-0	27-0

<sup>1</sup>includes wetlands, farmsteads and highways

<sup>2</sup>percent habitat available

<sup>3</sup>percent habitat use

shot 6 days after leaving the nest, and 1 suffered a leg injury 10 d after fledging and eventually died. The remaining 16 fledglings successfully left their natal ranges. Blair and Schitosky (1982), Ensign (1983) and Woffindin and Murphy (1983) observed no mortality during the post-fledging period among fledgling Ferruginous Hawks (N = 6, 2, 2, respectively).

#### CONCLUSION

This study of the post-fledging period of the Ferruginous Hawk provides information about the length of the post-fledging period, behavior observed, habitat utilized and observed mortality. The information presented can be used by land managers and land use planners to predict the period after fledging when Ferruginous Hawk fledglings and adults should be protected from disturbances that may affect mortality. While the mortality of 2 of 18 fledglings (11%) during this study may not be high for the short period studied, additional disturbances caused by local or regional developments may pose serious problems. The breeding range of Ferruginous Hawks encompasses many areas of intense energy development, including surface coal mining, oil, natural gas and geothermal exploration, drilling, exploitation, and powerline and pipeline construction. Ferruginous Hawks are a valuable indicator species due to their sensitivity to human disturbance and changes in prey popula-

tions associated with surface coal mining (Evans 1983). They may also be valuable indicators of the effects of other energy developments and the success of habitat mitigation or restoration efforts conducted in association with such developments. Energy-related development should proceed only with regard for the annual nesting chronology of Ferruginous Hawks, including the post-fledging period. Development should be delayed near active nests until 45 d after fledging to avoid disrupting post-fledging activities of Ferruginous Hawks. In some cases it may be beneficial to establish buffer zones surrounding Ferruginous Hawk nest sites. White et al. (1979) suggest restricting human activities to 0.8 km from nests and construction 1.6 km from nests. Planners working on activities not associated with energy development may also use this information to avoid disturbing Ferruginous Hawks during post-fledging activities. We urge that more investigators study the post-fledging period of raptors, as effective raptor management requires accurate information about this little-studied period in the life history of birds of prey.

#### ACKNOWLEDGMENTS

We gratefully acknowledge C.A. Faanes, A.R. Harmata, R.R. Olendorff, R. C. Stendell and P.F. Springer for reviewing early drafts of this paper.

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Received 1 February 1984; Accepted 1 November 1985

ERRATUM — Volume 19, Number 4, page 129, Table 1, S.R.B.P. (1979), should read . . . mammals 72%, birds 22%. In addition, S.R.B.P. Special Research Report (June 30, 1979, unreferenced) summarizes a 5-yr study of Prairie Falcon food items as . . . mammals 67%, birds 22%, reptiles 8%, invertebrates 2%.

## SHORT COMMUNICATIONS

### Observations of Nesting Northern Pygmy-Owls

DENVER W. HOLT AND WILLIAM D. NORTON

On 18 April 1981, nests of a Northern Pygmy-owl (*Glaucidium gnoma*) and Northern Saw-whet Owl (*Aegolius acadicus*) were discovered in the same tree in Missoula County, Montana (Norton and Holt 1982). We know of only one reported (Holman 1926) observation of nesting Northern Pygmy-owls in North America. The purpose of this paper is to summarize our observations and provide information on a little known North American species.

The nest was visited daily 4 April - 21 June 1981. Observations were made using binoculars and a variable power spotting scope from distances of 15-50 m. The owls were observed from the onset of their activity in late afternoon until activity ceased in the evening. Pellets and prey remains were collected from the nest for analysis after the nestlings fledged. Prey items were identified by cranial, dental and feather characteristics. Three prey items were retrieved after the male was observed caching them. Two others were observed in possession of the female. These observations are in addition to prey deliveries from male to female reported by Norton and Holt (1982).

The adult female pygmy-owl was observed each day at the cavity's entrance. These observations, and observations that the male never entered the cavity, indicate the female as the sole incubator and brooder. Each evening at dusk, the male called (a hollow, slow *toot-toot*) at approximately one sec intervals until the female came from the nest cavity to the area in which he was perched. Apparently this call solicited the female to receive prey from the male. Prey was exchanged in a small tree located approximately 10 m in front of the cavity entrance. A soft *twittering* vocalization was made by one or both owls during the exchange, followed by the departure of the male. The female either ate parts of the prey or returned to the cavity with it. A soft whistling sound was produced by the wings as each owl took flight.

Six eggs hatched on 13 May. On 25 May we heard what we believed were food begging calls of the nestlings for the first time. The *cheeping* call occurred when the female entered the nest cavity, whether or not she had prey. The nestlings were quiet when the female was absent. This behavior continued until the nestlings fledged on 5 and 6 June.

We never observed the male enter the nest cavity. On one occasion the female failed to emerge from the cavity for 11 min as the male called with prey. She then flew to the male and received the prey. The latest time at which the male was recorded to call was 2207 H. We stayed until after 2400 H on several nights.

Prey information was difficult to obtain. Pellets are small (average 17.5 x 9.6 mm; N = 26), roosting areas of the male difficult to locate, and the owls did not deposit pellets below the nesting cavity. Of the nineteen prey items identified, ten were mammals and nine were birds (Table 1).

During one observation at dusk, the female pygmy-owl attacked and killed a Red Squirrel (*Tamiasciurus hudsonicus*) on the ground and fed there. Similarly, in February 1982, we observed two other Northern Pygmy-owls preying on Bohemian Waxwing (*Bombycilla garrulus*) and caching and feeding on them on the ground and under bushes. Apparently, Northern Pygmy-owls are capable of killing large prey, but some prey may be too heavy to fly with and must be eaten or partially eaten on the ground.

Tail switching behavior by the adult owls was displayed only when we approached closely. The tail was switched from side to side with a quick, jerky motion. The distance between the observers and the tail switching owl was not measured; however, the behavior occurred whether or not the owl had prey. We observed the same behavior in wintering Northern Pygmy-owls. A description of the nest, nest tree and habitat type has been reported (Norton and Holt 1982).

Kellomaki (1977) labelled the site of prey exchange between the male and female European Pygmy-owl (*Glaucidium passerinum*) as the "sojourning sector", an area of prey delivery generally 10 - 30 m in front of the nest. We refer to this area as the "prey exchange area". Prey exchange between adults continued until the nestlings fledged, although the female began to hunt nine days after the eggs hatched. Kellomaki (1977) reported that the female European Pygmy-owl did not begin to hunt until the end of the nestling period.

Mikkola (1983) reported laying intervals of every second day for the European Pygmy-owl. Scherzinger (1970) and Kellomaki (1977) reported incubation periods of the European Pygmy-owl to be 28-30 d. Steyn (1979) reported the incubation period of the Pearl-spotted owl (*Glaucidium perlatum*) to be 29 d. Scherzinger (1970) and Steyn (1979) stated that incubation does not begin until the clutch is complete. Scherzinger (via Heimo Mikkola, pers. comm.) proved synchronous hatching in captive European Pygmy-owls. Norton and Holt (1982) also reported synchronous hatching in Northern Pygmy-owls. However, a female Northern Pygmy-owl from Montana sent by the authors to the Owl Rehabilitation Research Foundation, Vineland, Ontario, Canada, layed eggs in captivity which

Table 1. Prey remains from one pair of breeding Northern Pygmy-owls in Missoula County, Montana, 4 April - 21 June 1981. Prey items were identified from thirty-six pellets, debris from the nest, cached prey and observations.

PREY TYPE	NUMBER	METHOD OF DETECTION
<b>Birds</b>		
<i>Empidonax</i> spp.	1	from debris in nest
Hammond's Flycatcher ( <i>Empidonax hammondi</i> )	1	cache located
<i>Parus</i> spp.	1	from debris in nest
Red-breasted Nuthatch ( <i>Sitta canadensis</i> )	1	from debris in nest
Townsend's Solitaire ( <i>Myadestes townsendi</i> )	1	from debris in nest
Cassin's Finch ( <i>Carpodacus cassinii</i> )	1	from debris in nest
Unid. Passeriform birds (mandibles only)	3	from debris in nest and pellets
<b>Mammals</b>		
<i>Sorex</i> spp.	1	from debris in nest
Red Squirrel ( <i>Tamiasciurus hudsonicus</i> )	1	observation
Deer Mouse ( <i>Peromyscus maniculatus</i> )	1	from debris in nest
Northern Red-backed Vole ( <i>Clethrionomys gapperi</i> )	1	cache located
Unid. Microtine spp.	1	from debris in nest
House Mouse ( <i>Mus musculus</i> )	4	pellets, cache located
Western Jumping Mouse ( <i>Zapus princeps</i> )	1	observation
Totals	19	

hatched asynchronously (Kay McKeever, pers. comm.). Obviously, hatching in this genus warrants further investigation. Nestlings of European Pygmy-owls usually fledge on the same day, do not return to the nest, and nestlings that do not fledge at this time are left behind by the adults. (Heimo Mikkola, pers. comm.).

Assuming that the Northern Pygmy-owl, European Pygmy-owl and Pearl-spotted Owl have similar incubation periods, (28 days, Scherzinger 1979; 30 days, Kellomaki 1977; 29 days, Steyn 1979, respectively), we extrapolated that the eggs in this study were laid between 3 April and 15 April 1981, and incubation began approximately 15 April. The incubation period was calculated to be approximately 28 d, and the nestling period was 23 d. The fledglings were observed on six occasions between 7 and 14 June. The owls were not located after 14 June, and the study was terminated.

Observed tail switching behavior has been previously reported. Mailiard (1926) observed a bathing Northern Pygmy-owl jerking its tail from side to side, but he concluded that it was simply shaking off water. Steyn (1979) reported that "tail jerking" accompanied by head bobbing was a behavior linked to excitement in the Pearl-spotted Owl. We believe that tail switching was a direct consequence of our approach to Northern Pygmy-owls and

thus may indicate excitement or a threat display. The behavior needs further observation.

Reports on the food habits of Northern Pygmy-owls are scanty. To our knowledge, Holman (1926) recorded the only account of food habits during the breeding season prior to the accounts of Norton and Holt (1982). Holman (1926) observed nineteen prey exchanges between the male and female in California. Prey identified included eight lizards, five birds and six mammals. Fisher (1893) examined 6 stomachs of Northern Pygmy-owls and found 1 to contain a bird, 1 contained a mouse, 1 contained lizards, 1 contained an insect and 2 stomachs were empty. Other reports (Pierce 1921; Burleigh 1929; Brooks 1930; Clabaugh 1933; Castle 1937; Farley 1937; Brock 1958; and Gashwiler 1960) included few prey items of Northern Pygmy-owls at various times of the year.

Other interesting reports of Northern Pygmy-owl prey include incidental observations; Walker (1924) reported a Northern Pygmy-owl killing a young chicken (*Gallus domesticus*). Keck (1925) observed a Northern Pygmy-owl eating a chipmunk in Yosemite National Park. Kimball (1925) in Arizona and Balgooyen (1969) in California recorded Northern Pygmy-owls killing Gambel's Quail (*Callipepla gambelii*) and California Quail (*C. californica*), respectively. In California, Michael (1927) observed a



Northern Pygmy-owl to enter a woodpecker hole and take out a fully feathered nestling.

Though Mikkola (1970) collected pellets and prey remains from below the nest of European Pygmy-owls in Finland, we did not locate any pellets or prey remains below our Northern Pygmy-owl nest site, nor could we find any further indication in the literature that Northern Pygmy-owls deposit pellets or prey remains below their nests. Apparently the female at our nest deposited pellets and prey remains away from the nest site, and few remains were found in the cavity after the nesting period.

We thank Dale Becker, Gwilym Jones, Jeff Marks, Riley McClelland, Heimo Mikkola and Ian Nisbet for review, criticisms and suggestions on earlier drafts of the manuscript. We thank R.J. Clark and Brian A. Millsap for comments on the final draft. Kay McKeever provided captive breeding information. We thank her and the Owl Rehabilitation Research Foundation. We are thankful to Diane Boyd for photography and field assistance. Philip L. Wright and Richard Hutto from the University of Montana patiently answered our endless questions and provided ideas and encouragement. We thank them greatly. Finally, we are grateful to Nancy Claflin and the girls for providing financial support and faith in two undergraduates.

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Received 15 August 1985; Accepted 1 January 1986.

## An Unusual Incident with the Bald Eagle (*Haliaeetus leucocephalus*)

JERRY OLSEN

On 20 July 1969, I watched 2 immature Bald Eagles (*Haliaeetus leucocephalus*) feeding on the east shore of Lake Lebarge, Yukon Territory, Canada (opposite Richthofen Island - 61°10'N, 135° 05'W). The eagles were about 350 metres away from me and flushed when I walked towards them to investigate. I saw that the eagles had been feeding on the body of a man lying half submerged in the water. The body was fully clothed, and one trouser leg was ripped and the calf of that leg had been partly eaten.

I notified the Royal Canadian Mounted Police (RCMP) who collected the body. The RCMP informed me that the man had apparently been killed in Whitehorse, Yukon Territory, and had drifted down the Yukon River from there. The body probably had been submerged for about a month before rising and being washed ashore.

I know of no other reports of eagles (as opposed to vultures) eating human flesh.

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Received 25 July 1985; Accepted 1 August 1985

## TEMPORAL FLUCTUATIONS OF ROUGH-LEGGED HAWKS DURING CARRION ABUNDANCE

JAMES W. WATSON

Rapid local population changes in the wintering Rough-legged Hawk (*Buteo lagopus*) have been attributed to the movement of hawks following snowfall (Schnell 1967, 1968; Thurow et al. 1980) sometimes accompanied by dietary shifts to carrion (Klein and Mason 1981). When Black-tailed Jack Rabbit (*Lepus californicus*) populations peaked in southeastern Idaho in early 1980 (Stoddart 1983), rabbit carrion was overly abundant and available to the hawk population. To assess the influence of carrion abundance, snow depth, and minimum daily temperature on the seasonal abundance of hawks, I conducted a roadside raptor survey in winter 1982-83 and analyzed the association of these variables to hawk numbers by stepwise multiple regression (Zar 1974).

The 187 km survey was conducted weekly on the Idaho National Engineering Laboratory (INEL) between 11 November 1982 and 20 March 1983. Big sagebrush (*Artemisia tridentata*) and grass (*Agropyron* spp.) understory vegetation dominated along the survey route, which included 16.7 km of agricultural fields. A more complete description of vegetation patterns was given by Harniss and West (1973). To standardize the influence of wind and time of day on hawk behavior, surveys were conducted on calm, dry days between 0800 H and 1300 H MST but were occasionally delayed due to inclement weather. Vehicle traffic was consistently low on the INEL due to restricted public access and not considered to be an important influence on hawk numbers. The vehicle route and other survey methods followed that described by Craig (1978). Road-killed rabbits were tallied each survey and weather information was supplied by National Oceanographic and Atmospheric Administration (NOAA) (Central Facilities Area, INEL). Stepwise addition of variables (Zar 1974) was used to fit regressions, and the regression with the highest  $R^2_{adj}$  value judged to be the most suitable model.

A maximum of 53 and a minimum of 0 hawks were seen during 18 surveys ( $\bar{x} = 33 \pm 12$  hawks/survey). Rabbit carcasses counted during surveys varied from 0 to 268 ( $\bar{x} = 80 \pm 90$  carcasses/survey). Temperatures between October and April 1982-83 averaged 1.7° C, or 0.7° C above normal, and precipitation averaged 2.2 cm, or 0.4 cm above normal.

Single factor regression of hawks on carrion abundance, snow depth and minimum daily temperature on the day prior to the survey were significant ( $P < 0.05$ ), and explained 56.1, 26.1 and 29.9% of the variability in hawk numbers, respectively. Due to a difference in hawk counts observed for snow depths less than and greater than 10 cm, hawk counts were regressed on rabbit counts and a dummy variable (Zar 1974; Montgomery and Peck 1982) indicating snow depths of at least 10 cm. The addition of this variable was significant ( $R^2_{adj} = 0.65$ ,  $P < 0.001$ ). Addition of temperature and actual snow depths did not improve this regression ( $R^2_{adj} = 0.61$ ) and the following was determined to be the model which explained the most variation in hawk counts:

$$\hat{Y} = 19.09 + 0.07x_1 + 10.98x_2$$

Where Y = hawk count

$x_1$  = rabbit count

$x_2$  = 1 if snow depth > 10 cm, 0 if < 10 cm

Rough-legged Hawks have been described as "microtine specialists" that can shift to other prey when voles are unavailable

(White and Cade 1971). Snow depths, particularly above 10 cm, likely precluded small mammal use by hawks and they moved to roads to take advantage of increased carrion. Road-killed rabbits, which were the primary source of carrion, created a phenomenon similar to that for Bald Eagles (*Haliaeetus leucocephalus*) attracted to fish killed by powerplant operations (Ingram 1965) or fluctuations in water release rates at dams (Steenhof 1976). In both situations, a human-caused superabundance of carrion served to attract physiologically stressed raptors during winter. Such conditions probably "short-stopped" some Rough-legged Hawks migrating through the Snake River Plain during the early and latter part of the survey period, and accounted for a portion of the winter hawk population. Hawk counts were known to reflect the presence of transmitter-equipped resident hawks which shifted foraging territories to highways during inclement weather in winter 1982-83 (Watson 1984).

Although this species is known to take a variety of avian and mammalian prey (see review by Sherrod, 1978), prior accounts of carrion consumption (Weller 1964; Schnell 1967) are qualitative with carrion forming an insignificant portion of the total diet. During winter 1982-83, leporids comprised 48.6% of prey numbers and 70.1% of biomass of prey consumed by Rough-legged Hawks, whereas voles comprised 41.3% and 9.6%, respectively (Watson 1984). The reported variability in the consumption of carrion and movement of hawks to roads in cold weather (Schnell 1968; Bildstein 1978; Fleming 1981; Klein and Mason 1981), is evidently linked to winter range character. When snow cover reduces rodent availability, Rough-legged Hawks have the option of switching to alternate prey such as carrion, if it is available, or relocating to other areas.

## ACKNOWLEDGMENTS

This research was a contribution of the INEL Radioecology and Ecology Program, funded by the Office of Health and Environmental Research, Department of Energy in cooperation with the Fish and Wildlife Program, Department of Biology, Montana State University. Published as Journal Series No. 1729, Montana Agricultural Experiment Station. Thanks are extended to R.L. Eng, J.W. Grier, R.P. Howard and O.D. Markham for reviewing drafts of this note and to H. Lee, K. McGarigal and R.A. Watson for assistance.

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## Densities of Red-tailed Hawk Nests in Aspen Stands in the Piceance Basin, Colorado

MIKE MCGOVERN AND JOHN M. MCNURNEY

This note describes dissimilar nesting densities of the Red-tailed Hawk (*Buteo jamaicensis*) in 2 areas in Colorado. Although Red-tailed Hawks nest in a variety of habitats (Knight et al. 1982; Smith and Murphy 1982) hawks were observed nesting only in aspen (*Populus tremuloides*) trees.

Between 21 June and 1 July 1983, Red-tailed Hawk nests were surveyed in pure stands of aspen in 2 areas (designated A and B) in the Piceance Basin, Garfield County, Colorado. Areas A and B are approximately 38 and 28 km, respectively, north of Debeque, Mesa County, Colorado, at elevations between approximately 2400 and 2500 m. Both areas have similar types of vegetation. Area A was 28.7 km<sup>2</sup> in size and contained 24 aspen stands covering 3.1 km<sup>2</sup>. Area B was 14.0 km<sup>2</sup> in size and contained 17 aspen stands covering 2.8 km<sup>2</sup>. The remainder of the areas consisted primarily of shrubs (1 to 3 m in height) including mountain mahogany (*Cercocarpus montanus*), serviceberry (*Amelanchier utahensis*), Gambel oak (*Quercus gambelii*), big sagebrush (*Artemisia tridentata*) and others, with occasional areas composed of annual grasses.

Surveys of all aspen stands in both areas were done by helicopter (approximately 40% of the survey) or on foot. For those stands surveyed on foot, transects were walked at 50-m intervals following the elevational contours of each stand until all trees were examined. Nests were deemed occupied if young were seen in the nest, if the nest was recently decorated by greenery, or if a nest was

defended by an adult hawk. Locations of occupied nests were marked on 7.5-min topographical maps. Nearest neighbor analyses (Clark and Evans 1954) were conducted to determine if hawk nests were spaced randomly throughout each area.

Density of occupied nests was one/5.74 km<sup>2</sup> on area A, and mean distance between nests was 2.23 ( $\pm$  0.46 S.D.) km. Mean distance between nests in area B was 0.68 ( $\pm$  0.33 S.D.) km, with 1 breeding pair/2.00 km<sup>2</sup>. Mean density of nests and distances between nests on areas A and B were comparable with data found in the literature (Table 1). However, mean distance between nests on area B (0.68 km) was lower than all values reported (Table 1).

In area A, nearest neighbor analysis indicated that occupied nests tended toward uniform distribution and were significantly different from random ( $R = 1.84$ ;  $c = 3.60$ ,  $P < 0.01$ ). In area B, occupied nests were not significantly different from random distribution ( $R = 1.19$ ;  $C = 0.93$ ,  $P < 0.10$ ). The percentage of area covered by aspen on area A (11%) was less than that of area B (20%). In addition, there were more trees within the aspen stands on area A that were small (3-5 m high) (R.W. Beck and Associates 1983a, 1983b) and apparently ill-suited for Red-tailed Hawk nest sites. Therefore, available nesting habitat in the vicinity of occupied nests in area A may have been more limited than in area B. Indeed, there was a mean of 0.60 km<sup>2</sup> (range = 0.01 - 1.14 km<sup>2</sup>) of suitable nesting habitat (trees > 5m in height) within a 1-km radius of the nests in area A. In area B there was a mean of 1.04

Table 1. Nesting density and distance between Red-tailed Hawk nests.

AREA/BREEDING PAIR (KM <sup>2</sup> )	DISTANCE BETWEEN NESTS (KM)	SOURCE
7.5	1.79	McInville & Keith 1974
	2.13	
	2.05	
	1.90	
	1.60	
	2.40	
--	5.60	Knight et al. 1982
6.2	1.50	
--	3.30	
--	0.84	
--	6.40	Wiley 1975
5.1	1.76	
--	2.08	Hagar 1957
2.6	---	
1.3	1.76	Seidensticker & Reynolds 1971
8.8	---	
6.2	---	Gates 1972
6.9	---	
24.9	---	Fitch et al. 1946
7.9	---	
		Orians & Kuhlman 1956
		Luttich et al. 1971
		Corman 1973
		in Springer & Kirkley 1978
		Johnson 1975
7.7 ± 6.8	2.5 ± 1.58	$\bar{x} \pm$ S.D. of reported values
5.74	2.23	This study, Area A mean (N = 5)
2.00	0.68	
		This study, Area B mean (N = 6)

km<sup>2</sup> (range = 0.62 - 1.48 km<sup>2</sup>) of suitable habitat within a 1-km radius of nests in that area. Although dissimilar, the means were not statistically different (Student's *t* test;  $0.05 < p < 0.10$ ).

Newton (1976) suggested that Red-tailed Hawk densities are determined by availability of nesting sites and food. Thus, an explanation for the lower density of nests and the greater distances between nests on area A may have been availability of nesting sites. However, the apparently high density of nests and low mean distance between nests on area B remains unexplained.

#### ACKNOWLEDGMENTS

We thank Dr. Clayton M. White of Brigham Young University for his helpful comments on this note.

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Received 15 April 1985; Accepted 1 July 1985

## THESIS ABSTRACTS

### THE SHARP-SHINNED HAWK (*Accipiter striatus Vieillot*) IN INTERIOR ALASKA

Breeding ecology of the Sharp-shinned Hawk (*Accipiter striatus*) was studied at 19 nests in interior Alaska from 1978 to 1981. Hawks nested in conifers in dense, young stands of mixed deciduous and coniferous trees. Sharp-shins primarily ate small birds, apparently hunted the most productive habitats and captured prey in proportion to availability. Growth and food requirements of 4 captive-reared nestlings were monitored to supplement data on wild young. A typical family required an estimated 13,620 g of prey during the breeding season. In comparison to other studies, Sharp-shinned Hawks in Alaska 1) reoccupied old nest areas more frequently, 2) occupied smaller home ranges, 3) nested in greater densities, 4) completed breeding cycles more quickly, 5) laid more eggs and 6) hatched and fledged more young. In future studies, which are important because of the sharp-shin's extensive range and susceptibility to pollution and habitat destruction, Alaskan birds could serve as standards of comparison. — **Clarke, Ronald Gordon. 1984. M.S. Thesis, University of Alaska, College, Alaska.**

### CHARACTERIZATION OF NESTING HABITAT OF GOSHAWKS (*Accipiter gentilis*) IN NORTHWESTERN CALIFORNIA

Habitat use of nesting Goshawks (*Accipiter gentilis*) was studied during 3 breeding seasons in Six Rivers National Forest, Humboldt and Trinity Counties, California. Habitat characteristics of the nesting areas were examined on 4 levels: community patterns, nest stand, nest site and the nest and nest tree, for 10 nests. Nest stands typically were dense single-storied stands of young Douglas-fir (*Pseudotsuga menziesii*) with scattered hardwood components and large mature trees and a park-like understory. Locations varied in slope and elevation, but consistently faced northeast. Nest sites typically were small stands of dense mature trees within the nest stands. Tree density and canopy closure were less in nest sites than in the surrounding nest stands. Nests generally were constructed of sticks, were adjacent to the stem, and were below or within the lower quarter of the canopy on the downslope side of a Douglas-fir. Distance to the nearest water source and human disturbance ranged widely. Potentially suitable foraging and alternate nesting areas averaged 41 m and 30 m respectively from the nest tree. — **Hall, Patricia A. 1984. M.S. Thesis, Humboldt State University, Arcata, California.**



## DISTRIBUTION AND DENSITY OF THE FOUR COMMON PASSERINES IN WEST GREENLAND

Quantitative analyses of songbird distribution, influence of boulders and depressions of numbers near Peregrine Falcon (*Falco peregrinus*) eyries have not been previously reported for inland west Greenland. In the present study passerine distribution, habitat utilization, density and response to nesting Peregrine Falcons were determined by conducting line transects near eyries and on the open tundra. Passerine distribution is strongly influenced by habitat and presence of boulders. A marked depression in passerine numbers was recorded within 400 m of active peregrine eyries. Densities were estimated as 0.23 - 0.38 birds/ha. Density estimates are lower than those reported from several Arctic areas. — **Meese, Robert J. 1984. M.S. Thesis, Brigham Young University, Provo, Utah.**

## A PHENOLOGY OF WINTERING BALD EAGLES IN THE CHILKAT VALLEY, ALASKA

Communal winter feeding and roosting Bald Eagles, (*Haliaeetus leucocephalus alascanus*), between September and March, 1977-78 and 1978-79. During this period 110 censuses were conducted. Twenty-one environmental, population and habitat use variables were quantified; these data were analyzed using bivariate and univariate statistical procedures to ascertain the effects of environmental variation on the population dynamics and habitat use of Bald Eagles wintering in an undisturbed communal roost.

Immigration of Bald Eagles into the Chilkat Valley began the first week of October. The major influxes of eagles occurred between the second week of October and the second week of November. A peak number of 2,578 eagles was recorded in 1977 on 8 November and in 1978 a peak number of 2,254 was recorded on 24 December. Emigration from the area was completed in the last week of March in 1978 and the third week of February in 1979. The percentage of juvenile eagles in the population decreased from the second week of October to March. Eagles were distributed throughout the valley during autumn. In the second week of November they concentrated in the ice-free area where spawned-out salmon were available. Intense feeding activity was significantly correlated with above-freezing temperatures that accompanied severe wind chill conditions froze the salmon carcasses. During these periods the eagles would abandon the feeding areas and utilization of trees for shelter increased significantly. The number of eagles observed decreased by approximately 30% when cold, clear weather persisted, but increased with the return of warmer, overcast weather. — **Waste, Stephen McIntosh. 1985. M.Sc. Thesis, Humboldt State University, Arcata, California. 86 pp.**

## BEHAVIOR AND HABITAT USE OF BREEDING NORTHERN HARRIERS IN SOUTHWESTERN IDAHO

Radiotelemetric and visual monitoring of 4 breeding Northern Harrier (*Circus cyaneus*) pairs in predominantly sagebrush (*Artemisia* sp.) habitat of the Snake River Bird of Prey Study Area, Idaho, indicated that harriers used riparian and cultivated habitats disproportionately. Males were observed in an apparent habitat and prey shift, changing from Meadow Voles (*Microtus pennsylvanicus*) in alfalfa (*Medicago sativa*) fields as growth approached 46 cm, to Whip-tailed Lizards (*Cnemidophorus tigris*) in open sagebrush habitat. Home ranges of males were estimated at 15.7 km<sup>2</sup>, while those of females were estimated at 1.13 km<sup>2</sup>. Males were far ranging and were observed at distances of 9.5 km from the nest. Male hunting activities were highest in the second week post-hatching. Most of the time both males and females were observed resting or preening less than 0.5 km from the nest. — **Martin, John W. 1984. M.S. Thesis, Brigham Young University, Provo, Utah.**

RAPTOR INVENTORY AND FERRUGINOUS HAWK BREEDING BIOLOGY  
IN SOUTHEASTERN OREGON

Raptor inventories were conducted in southeastern Oregon in 1979 and 1980 on extensive study areas, and on randomly selected 10.4-km<sup>2</sup> study units. Overall raptor densities ranged from 10-23 pair/100 km<sup>2</sup>. Estimates of Golden Eagle (*Aquila chrysaetos*) densities are 2-4 and 4-5 pair/100 km<sup>2</sup>, respectively. An important nesting area for Ferruginous Hawk (*Buteo lagopus*) and Prairie Falcon was discovered near Vale, Oregon. In 1980, 32 nesting pairs of Ferruginous Hawks were located on a 312 km<sup>2</sup> study area. Clutch size averaged 3.9, and 3.2 young fledged/nesting attempt. This is one of the densest and most productive populations of Ferruginous Hawks ever reported. Ferruginous Hawks nested on the ground, on outcrops and on cliffs. They preyed upon Townsend Ground Squirrel (*Spermophilus townsendii*) almost exclusively. Ground squirrel distribution is related to soil characteristics. Soils with shallow duripans or clay appear to be unfavorable ground squirrel habitats. Vegetation parameters account for 28 percent of the observed variability in ground squirrel hole counts along transects. Crested wheatgrass seedlings are occupied by ground squirrels and are compatible with Ferruginous Hawk management in the study area. The over-riding influence of soil type on ground squirrel distribution suggests that soil maps may be an effective way of locating areas with a high potential for raptor nesting concentrations. A survey of Oregon wildlife biologists determined that 100 active Ferruginous Hawk nests have been identified in Oregon. — **Lardy, Michael Edward. 1980. M.S. Thesis, University of Idaho, Moscow.**

THE PEREGRINE FALCON (*Falco peregrinus*) IN SOUTHERN BRAZIL:  
ASPECTS OF WINTER ECOLOGY IN AN URBAN ENVIRONMENT

The study was undertaken in an urban environment of Porto Alegre, Brazil (30 02" S and 51 13" W), during 2 austral summers (December 1978 to March 1979 - January to March 1980). Seven falcons (4 ♂♂; 3 ♀♀) were observed between December 1978 and March 1979. Five of the falcons were adults, 1 a juvenile and 1 of unknown age. The resident pair and 1 transient adult were phenotypically similar to the Arctic Peregrine Falcon (*Falco peregrinus tundrius*) in North America. An adult pair of peregrines were monitored for 540 hours. Sequences of mating behavior, such as aerial displays and courtship flights, were recorded during the study. The resident female showed strong territoriality towards other females. The pair was most active during early morning and evening, and rested in mid-day on shady ledges. Feeding activities increased from February to March, suggesting premigratory fattening. Foods of the resident female consisted mainly of pigeons (91% of the prey remains), showing preference for fledglings taken from nests on skyscraper ledges. The resident male fed mostly on bats and passerines. Predation on bats was recorded mainly in November and December. The resident female apparently took heavy prey (above 300 g) near her plucking ledge and light prey (below 100 g) when far away, implying an energy cost minimization in transportation during the flight. The male was more opportunistic in feeding behavior than the female. — Albuquerque, Jorge, L.B. 1984. M.S. Thesis, Brigham Young University, Provo, Utah.

DISSERTATION ABSTRACTS

ELECTRORETINOGRAPHIC RESPONSES AND RETINAL ULTRASTRUCTURE  
OF THE GREAT HORNED OWL, *Bubo virginianus*

This study was an investigation of the function and ultrastructure of the retina of the Great Horned Owl (*Bubo virginianus*). Gross physiological function of the retina was determined by electroretinography. Two procedures, dark-adaptation and flicker stimuli, were used to determine the relative contributions of the rod (scotopic) and cone (photopic) systems in these retinæ. A total of 8 retinæ from 4 Great Horned Owls provided data for this study. Owls were anesthetized and placed in a hand-built optical apparatus in which light of various wavelengths and intensities could be delivered to the subject's eye. The dark-adaptation procedure revealed that the retina of this species was dominated by scotopic (rod-generated) components, as indicated by a slow, steady rise in  $\beta$ -waves were also broad and rounded and had a fairly long time course. This suggested that recovery of the retina following exposure to light was primarily due to an abundance of rods in the retina. Additionally, some cone activity was observed when high intensity single-flash stimuli were used. This was indicated by prominent  $\alpha$ -waves and  $\beta$ -waves with steeper peaks and short time courses. Flicker ERGs revealed a scotopic fusion frequency of approximately 16 Hz. Photopic fusion frequencies were in the range of 35-45 Hz which was quite lower than human and other diurnal primate retina. These data indicated that while cones were present in the Great Horned Owl retina and contributed to photopic responses, the number of cones was low.

This study was the first description of retinal ultrastructure in the Great Horned Owl. A total of 10 retinæ from 5 Great Horned Owls provided material for electron microscopy. Subjects were euthanized and retinæ were prepared according to standard procedures. Ultrastructural observations of the retina confirmed previous observations by myself (Ault, S.J., *Raptor Research*, 18(2):62-66, 1984) and others (Oehme, H., *Der Zool. Jahrb. Abt. 2*, 79:439-478, 1961; Fite, K., *Vision Research*, 13:219-230, 1973) that the retina of the Great Horned Owl possesses a high number of rods, but also contains some cones. Analysis of the ultrastructure of the retina revealed typical neuro-anatomical arrangements for a rod-dominated vertebrate retina. However, several structures not previously reported for this species were also identified. These included: 1) the presence of double cones in the receptor layer, 2) the apparent lack of electrical contacts between adjacent photoreceptors despite the presence of lateral fins on the inner segments, 3) the myelination of ganglion cell axons within the nerve fiber layer.

This study concluded that the retina of the Great Horned Owl is adapted to function optimally during the low illuminance levels at night. However, the presence of a functional photopic system and the ultrastructural arrangements of the retina may allow this owl to function in the brighter illuminances of the day. This owl is occasionally active during the day and its retina is apparently adapted for this possibility and is not relegated to a strict nocturnal category. Such adaptation allows the Great Horned Owl to be an effective nocturnal predator while at the same time allowing it to expand its activity into the diurnal realm if needed.

Ault, Steven J. 1985. Ph.D. Dissertation. Idaho State University, Pocatello, Idaho. Present address: Department of Anatomy, University of Utah School of Medicine, Salt Lake City, Utah 84132. Dissertation directed by Dr. Edwin W. House, Dept. of Biological Sciences, Idaho State University.

## NEWS AND REVIEWS

### Reviewers for *Raptor Research*, 1985

Commensurate with the growth of The Raptor Research Foundation, Inc., has been an increase in the diversity of subject matter of manuscripts received for publication in *Raptor Research*. Throughout the year, numerous individuals have generously given of their time and expertise while serving as reviewers for manuscripts submitted to the Editorial Office. The Editorial Staff is continuing to expand the list of individuals who serve as reviewers for *Raptor Research*, and the individuals listed below have served as reviewers during 1985. The Editorial Staff expresses its sincere appreciation to them for a job well done. Those individuals who have contributed reviews of two or more manuscripts are indicated by an asterisk.

Thomas G. Balgooyen, J.R. Barnes, Gary Bartolotti, Keith L. Bildstein, David M. Bird\*, Tom J. Cade, Charles T. Collins, Michael W. Collopy, A.L. Clark, Richard J. Clark\*, William S. Clark, David H. Ellis, James H. Enderson, David L. Evans, George F. Gee, Sidney A. Gauthreaux, Jr., Jon Gerrard, James A. Gessaman, E.F. Graham, James D. Grier, Curtice Griffin, Frances Hamerstrom, Frederick Hamerstrom, Al Harmata\*, Ed Henckel, Richard P. Howard\*, Grainger Hunt, Jerome A. Jackson\*, Fran James, Richard Johnstone, Michael N. Kochert\*, Richard L. Knight\*, P.E. Lake, Jeffrey L. Lincer, David M. Lyons\*, Helmut C. Mueller\*, Morlan W. Nelson, R. Wayne Nelson\*, Ian Newton\*, Stephen W. Platt, Sergej Postupalsky\*, David T. Rogers, Jr., Christopher Servheen, Dennis K. Shiozawa, Dwight G. Smith, Karen Steenhoff, Stanley A. Temple\*, Kimberly Titus, F. Prescott Ward, Stanley N. Wiemeyer, E. William Wischusen.

**The Raptor Research Foundation, Inc. announces Raptor Organization Registry. Statement of Purpose:** Raptor is here defined as including all species of the traditional avian orders Falconiformes and/or Strigiformes. To borrow a statement from the British Trust for Ornithology (BTO News, December 1978, No. 97) concerning the purpose of this registry it "is an exercise in communication." There are, in the world, numerous splendid organizations whose major purpose is to deal with some aspect of the life of raptors, unfortunately their number, location(s), and specific purpose(s) are unknown to any organization or individual with the need to know. The Raptor Research Foundation is interested in identifying locations and purposes of as many of these organizations as possible and your cooperation in accomplishing this task would be greatly appreciated. It is RRF's intent to assemble a document compiling the results and provide each responding organization with a copy of this compilation to facilitate communication and to make it available to other organizations, e.g., wildlife or conservation agencies, funding agencies, etc.

Officers of organizations dealing with some aspect of the life of raptors are asked to submit the following information for inclusion in **A Directory of Raptor Organizations of the World:** official organization name; address [permanent address if there is one]; brief Statement of Purpose; approximate number of members; major area(s) of interest, i.e., basic research, captive breeding of raptors, conservation, education, falconry, general aspects, raptor movement or rehabilitation; name and official position of responding individual. His information should be forwarded [on an organizational letterhead if one is available] to: **Richard J. Clark, Vice President, The Raptor Research Foundation, Inc., Department of Biology, York College of Pennsylvania, York, PA 17403-3426 USA.**

**Proceedings of the Southeastern United States and Caribbean Osprey Symposium** —published by The International Osprey Foundation, Inc., edited by Mark A. Westall. Eleven papers, 132 pages. Copies can be ordered from The International Osprey Foundation, Inc., P.O. Box 250, Sanibel, FL 33957 USA. Price: \$16.00 U.S.

## ANNOUNCEMENTS

### **The Leslie Brown Memorial Fund**

The late Leslie Brown of Karen, Kenya, was one of the most inspired and productive raptor biologists of recent decades. His inventive research and thorough documentation of the status, life histories, and behavior of birds of prey from several continents have set high standards for all who remain as his students. In memory of Leslie and his many accomplishments, The Raptor Research Foundation, Inc., has established the Leslie Brown Memorial Fund. Proposals, on raptor research or the dissemination of information on raptors, should be submitted by **August 31, 1986**. Proposals concerning African raptors will receive highest priority.

Proposals and inquiries about tax exempt contributions to the fund should be sent to: Dr. Jeff Lincer, Chairman, RRF Leslie Brown Memorial Fund, 4718 Dunn Drive, Sarasota, FL 33583 USA.

### **Symposium on Northern Forest Owls, Winnipeg, Manitoba, Canada, 3-7 February 1987 — Formal Call for Abstracts.**

A symposium on the biology and conservation of Northern Forest Owls of the world will be held in Winnipeg, Manitoba, from 3-7 February 1987. This letter is a call for abstracts of papers to be considered for presentation at the symposium and possible inclusion in the published proceedings.

The Program Committee consists of Drs. Richard J. Clark (USA), Erkki Korpimäki (Finland), Robert W. Nero (Canada), Ronald A. Ryder (USA), and myself as chairman. We hope to bring together speakers whose papers will be published under the tentative title "Owls of the Northern Forests." The symposium's length will be determined by the number of papers submitted, with time being allotted accordingly. Each contribution is to be based on original work not published elsewhere. The refereed proceedings will be published in an appropriate fashion.

If you are interested in participating in the symposium, please contact me and provide an abstract or brief description of your proposed contribution. Please pass this information on to your co-workers or students who may not be aware of the symposium. Appropriate topics include: influence of prey population fluctuations on reproduction, annual and seasonal movements, dispersion and dispersal, influence of forest alteration, population dynamics, roosting dynamics, census techniques, habitat management of conservation, behavior, energetics, and so on. To ensure that your paper will be considered for publication in the proceedings we request that you submit a copy of your paper by **15 January 1987**.

The intent of this symposium is to draw together people from around the world who are interested in Northern Forest Owls. This will provide an opportunity for an exchange of information as well as personal contact with fellow workers. Your attendance will enhance these objectives.

Spencer G. Sealy

University of Manitoba Dept. of Zoology, Winnipeg, Manitoba, Canada R3T 2N2

# R A P T O R   R E S E A R C H

A QUARTERLY PUBLICATION OF THE RAPTOR RESEARCH FOUNDATION, INC.

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*Raptor Research* (ISSN 0099-9059) welcomes original manuscripts dealing with all aspects of general ecology, natural history, management and conservation of diurnal and nocturnal predatory birds. Send all manuscripts for consideration and books for review to the Editor. Contributions are welcomed from throughout the world, but must be written in English.

**INSTRUCTIONS FOR CONTRIBUTORS:** Submit a typewritten original and two copies of text, tables, figures and other pertinent material to the Editor. Two original copies of photographic illustrations are required. *Raptor Research* is published in a double-column format and authors should design tables and figures accordingly. **All submissions must be typewritten double-spaced** on one side of 8½ x 11-inch (21½ x 28 cm) good quality, bond paper. Number pages through the Literature Cited section. The cover page should contain the full title and a shortened version of the title (not to exceed 30 characters in length) to be used as a running head. Author addresses are listed at the end of the Literature Cited section. Authors should indicate if present addresses are different from addresses at the time the research was conducted. When more than one author is listed, please indicate who should be contacted for necessary corrections and proof review. Provide an abstract for each manuscript more than 4 double-spaced typewritten pages in length. Abstracts are submitted as a separate section from the main body of the manuscript and should not exceed 5% of the length of the manuscript. Acknowledgments, when appropriate, should immediately follow the text and precede the Literature Cited. Both scientific and common names of all organisms are always given where first appearing in the text and should conform to the current checklists, or equivalent references, such as the A.O.U. Checklist of North American Birds (6th ed., 1983). Authors should ensure that all text citations are listed and checked for accuracy. If five or fewer citations appear in the text, place the complete citation in the text, following these examples: (Brown and Amadon, Eagles, Hawks and Falcons of the World. McGraw-Hill, New York. 1968), or Nelson (*Raptor Res.* 16(4):99, 1982). If more than five citations are referenced, each should include author and year (e.g., Galushin 1981), or in a citation with three or more authors, the first author and year (e.g., (Bruce et al. 1982)). Citations of two or more works on the same topic should appear in the text in chronological order (e.g., (Jones 1977, Johnson 1979 and Wilson 1980)). Unpublished material cited in the text as "pers. comm.," etc., should give the full name of the authority, but must not be listed in the Literature Cited section. If in doubt as to the correct form for a particular citation, it should be spelled out for the Editor to abbreviate.

Metric units should be used in all measurements. Abbreviations should conform with the Council of Biology Editors (CBE) Style Manual, 4th ed. Use the 24-hour clock (e.g., 0830 and 2030) and "continental" dating (e.g., 1 January 1984).

Tables should not duplicate material in either the text or illustrations. Tables are typewritten, **double-spaced throughout**, including title and column headings, should be separate from the text and be assigned consecutive Arabic numerals. Each table must contain a short, complete heading. Footnotes to tables should be concise and typed in lower-case letters. Illustrations (including coordinate labels) should be on 8½ x 11-inch (21½ x 28 cm) paper and must be submitted flat. Copies accompanying the original should be good quality reproductions. The name of the author(s) and figure number should be penciled on the back of each illustration. All illustrations are numbered consecutively using Arabic numerals. Include all illustration legends together, typewritten **double-spaced**, on a single page whenever possible. Line illustrations (i.e., maps, graphs, drawings) should be accomplished using undiluted india ink and designed for reduction by 1/3 to 1/2. Drawings should be accomplished using heavy weight, smooth finish, drafting paper whenever possible. Use mechanical lettering devices, pressure transfer letters, or calligraphy. Typewritten or computer (dot matrix) lettering is **not** acceptable for illustrations. Use of photographic illustrations is possible but requires that prior arrangements be made with the Editor and the Treasurer.

A more detailed set of instructions for contributors appeared in *Raptor Research*, Vol. 18, No. 1, Spring 1984, and is available from the Editor.



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